fNIRS publications on PubMed: Jun2018-Jan2019

Felipe Orihuela-Espina

Methodology. Searches were made in PubMed constraining the search period between June 1, 2018 and February, 28, 2019. 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

Conducting Hyperscanning Experiments with Functional Near-Infrared Spectroscopy.
Reindl V, Konrad K, Gerloff C, Kruppa JA, Bell L, Scharke W.
J Vis Exp. Jan 19;(143).
doi: 10.3791/58807.

Concurrent brain recordings of two or more interacting persons, an approach termed hyperscanning, are gaining increasing importance for our understanding of the neurobiological underpinnings of social interactions, and possibly interpersonal relationships. Functional near-infrared spectroscopy (fNIRS) is well suited for conducting hyperscanning experiments because it measures local hemodynamic effects with a high sampling rate and, importantly, it can be applied in natural settings, not requiring strict motion restrictions. In this article, we present a protocol for conducting fNIRS hyperscanning experiments with parent-child dyads and for analyzing brain-to-brain synchrony. Furthermore, we discuss critical issues and future directions, regarding the experimental design, spatial registration of the fNIRS channels, physiological influences and data analysis methods. The described protocol is not specific to parent-child dyads, but can be applied to a variety of different dyadic constellations, such as adult strangers, romantic partners or siblings. To conclude, fNIRS hyperscanning has the potential to yield new insights into the dynamics of the ongoing social interaction, which possibly

go beyond what can be studied by examining the activities of individual brains.

Demonstrating Brain-Level Interactions Between Visuospatial Attentional Demands and Working Memory Load While Driving Using Functional Near-Infrared Spectroscopy.

Scheunemann J, Unni A, Ihme K, Jipp M, Rieger JW.

Front Hum Neurosci. Jan 23;12:
doi: 10.3389/fnhum.2018.00542. eCollection 2018.

Driving is a complex task concurrently drawing on multiple cognitive resources. Yet, there is a lack of studies investigating interactions at the brain-level among different driving subtasks in dual-tasking. This study investigates how visuospatial attentional demands related to increased driving difficulty interacts with different working memory load (WML) levels at the brain level. Using multichannel whole-head high density functional near-infrared spectroscopy (fNIRS) brain activation measurements, we aimed to predict driving difficulty level, both separate for each WML level and with a combined model. Participants drove for approximately 60 min on a highway with concurrent traffic in a virtual reality driving simulator. In half of the time, the course led through a construction site with reduced lane width, increasing visuospatial attentional demands. Concurrently, participants performed a modified version of the n-back task with five different WML levels (from 0-back up to 4-back), forcing them to continuously update, memorize, and recall the sequence of the previous 'n' speed signs and adjust their speed accordingly. Using multivariate logistic ridge regression, we were able to correctly predict driving difficulty in 75.0% of the signal samples (1.955 Hz sampling rate) across 15 participants in an out-of-sample cross-validation of classifiers trained on fNIRS data separately for each WML level. There was a significant effect of the WML level on the driving difficulty prediction accuracies [range 62.2-87.1%; ?2(4) = 19.9, p < 0.001, Kruskal-Wallis H test] with highest prediction rates at intermediate WML levels. On the contrary, training one classifier on fNIRS data across all WML levels severely degraded prediction performance (mean accuracy of 46.8%). Activation changes in the bilateral dorsal frontal (putative BA46), bilateral inferior parietal (putative BA39), and left superior parietal (putative BA7) areas were most predictive to increased driving difficulty. These discriminative patterns diminished at higher WML levels indicating that visuospatial attentional demands and WML involve interacting underlying brain processes. The changing pattern

of driving difficulty related brain areas across WML levels could indicate potential changes in the multitasking strategy with level of WML demand, in line with the multiple resource theory.

Multi-modal neuroimaging of dual-task walking: Structural MRI and fNIRS analysis reveals prefrontal grey matter volume moderation of brain activation in older adults.

Wagshul ME, Lucas M, Ye K, Izzetoglu M, Holtzer R.

Neuroimage. Jan pii: S1053-8119(19)30052-
doi: 10.1016/j.neuroimage.2019.01.[Epub ahead of print]

It has been well established over the last two decades that walking is not merely an automatic, motoric activity; it also utilizes executive function circuits, which play an increasingly important role in walking for older people and those with mobility and cognitive deficits. Dual-task walking, such as walking while performing a cognitive task, is a necessary skill for everyday functioning, and has been shown to activate prefrontal lobe areas in healthy older people. Another well-established point in healthy aging is the loss of grey matter, and in particular loss of frontal lobe grey matter volume. However, the relationship between increased frontal lobe activity during dual-task walking and loss of frontal grey matter in healthy aging remains unknown. In the current study, we combined oxygenated hemoglobin (HbO2) data from functional near-infrared spectroscopy (fNIRS), taken during dual-task walking, with structural MRI volumetrics in a cohort of healthy older subjects to identify this relationship. We studied fifty-five relatively healthy, older participants (=65 years) during two separate sessions: fNIRS to measure HbO2 changes between single-task (i.e., normal walking) and dual-task walking-while-talking, and high-resolution, structural MRI to measure frontal lobe grey matter volumes. Linear mixed effects modeling was utilized to determine the moderation effect of grey matter volume on the change in prefrontal oxygenated hemoglobin between the two walking tasks, while controlling for covariates including task performance. We found a highly significant interaction effect between frontal grey matter volume and task on HbO2 levels ($p < 0.0001$). Specifically, increased HbO2 levels during dual-task compared to single-task walking were associated with reduced frontal grey matter volume. Regional analysis identified bilateral superior and rostral middle gyri as the primary areas driving these results. The findings provide support for the concept of neural inefficiency: in the absence of behavioral gains, grey matter loss in relatively healthy, older individuals leads

to over-activation of frontal lobe during a cognitively demanding walking task with established clinical and predictive utility.

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fNIRS Assessment during an Emotional Stroop Task among Patients with Depression: Replication and Extension.

Nishizawa Y, Kanazawa T, Kawabata Y, Matsubara T, Maruyama S, Kawano M, Kinoshita S, Koh J, Matsuo K, Yoneda H.

Psychiatry Investig. Jan;16(1):80-
doi: 10.30773/pi.2018.11.12.Epub Jan 25.

OBJECTIVE: Accumulated evidence collected via functional near-infrared spectroscopy (fNIRS) has been reported with regard to mental disorders. A previous finding revealed that emotional words evoke left frontal cortex activity in patients with depression. The primary aim of the current study was to replicate this finding using an independent dataset and evaluate the brain region associated with the severity of depression using an emotional Stroop task. METHODS: Oxygenized and deoxygenized hemoglobin recording in the brain by fNIRS on 14 MDD patients and 20 normal controls. RESULTS: Hyperactivated oxygenized hemoglobin was observed in the left frontal cortex on exposure to unfavorable stimuli, but no significant difference was found among patients with depression compared with healthy controls on exposure to favorable stimuli. This result is consistent with previous findings. Moreover, an evoked wave associated with the left upper frontal cortex on favorable stimuli was inversely correlated with the severity of depression. CONCLUSION: Our current work using fNIRS provides a potential clue regarding the location of depression symptom severity in the left upper frontal cortex. Future studies should verify our findings and expand them into a precise etiology of depression.

The Positive Brain - Resting State Functional Connectivity in Highly Vital and Flourishing Individuals.

Goldbeck F, Haipt A, Rosenbaum D, Rohe T, Fallgatter AJ, Hautzinger M, Ehlis AC.

Front Hum Neurosci. Jan 14;12:
doi: 10.3389/fnhum.2018.00540. eCollection 2018.

The World Health Organization has defined health as "complete physical, mental and social well-being and not merely the absence of disease

or infirmity" (World Health Organization, 1948). An increasing number of studies have therefore started to investigate "the good life." However, the underlying variation in brain activity has rarely been examined. The goal of this study was to assess differences in resting state functional connectivity (RSFC) between regular healthy individuals and healthy individuals with a high occurrence of flourishing and subjective vitality. Together, flourishing, a broad measure of psycho-social functioning and subjective vitality, an organismic marker of subjective well-being comprise the phenomenological opposite of a major depressive disorder. Out of a group of 43 participants, 20 high-flourishing (highFl) and 18 high-vital (highSV) individuals underwent a 7-min resting state period, where cortical activity in posterior brain areas was assessed using functional near-infrared spectroscopy (fNIRS). Network-based statistics (NBS) of FC yielded significantly different FC patterns for the highFl and highSV individuals compared to their healthy comparison group. The networks converged at areas of the posterior default mode network and differed in hub nodes in the left middle temporal/fusiform gyrus (flourishing) and the left primary/secondary somatosensory cortex (subjective vitality). The attained networks are discussed with regard to recent neuroscientific findings for other well-being measures and potential mechanisms of action based on social information processing and body-related self-perception.

Treading on the unknown increases prefrontal activity: A pilot fNIRS study.

Koren Y, Parmet Y, Bar-Haim S.

Gait Posture. Jan 21;69:96-
doi: 10.1016/j.gaitpost.2019.01.[Epub ahead of print]

BACKGROUND: Complex walking conditions (e.g. dual tasking) have been associated with increased prefrontal (PFC) activity. However, most paradigms include a predictable environment, specifically, a predictable walking terrain. In the present study we investigate PFC activity under an unusual walking condition where each foot placement was on unexpected terrain, thus causing a mismatch between visuospatial perception and lower-extremity proprioception. RESEARCH OBJECTIVE: To assess whether PFC activity increases under unstable unpredictable conditions compared to unstable but predictable conditions. METHODS: This was a prospective study involving twenty healthy adults. Participants walked in two conditions: unstable but predictable, and unstable and unpredictable. To assess

walking stability, both stride-time (ST) and stride-time variability (CV) were measured. To assess PFC activity, two wireless near-infrared spectroscopy devices were used. The group hemodynamic response (GHR) was calculated for each condition. For statistical analysis, a linear-mixed-effects model was used. RESULTS: Walking with unpredictable perturbations did not change the ST (t?=?0.51, p?=?0.61) but significantly increased the parameter CV (t?=?11.74, p?<?0.001). The GHR of both conditions indicated brief per-initiation PFC activity that was similar across conditions. However, when GHRs were calculated relative to normal walking (i.e., the participants' own shoes), continuous activity was evident. Compared to the predictable condition, the unpredictable condition significantly increased this activity during steady-state walking (t?=?2.13, p?=?0.033). SIGNIFICANCE: Observations from the present study suggest that at least two neural components are present in the measured signal-a brief one, occurring per-initiation, and a continuous one, sensitive to the predictability of the terrain. The second component was accompanied by a decrease in walking stability. These results may contribute to our understanding of the control mechanism underlying gait and future planning of rehabilitation protocols.

Functional near-infrared spectroscopy-based affective neurofeedback: feedback effect, illiteracy phenomena, and whole-connectivity profiles.

Trambaiolli LR, Biazoli CE Jr, Cravo AM, Falk TH, Sato JR.

Neurophotonics. Jul;5(3):
doi: 10.1117/1.NPh.5.3.Epub 2018 Sep 18.

Background: Affective neurofeedback constitutes a suitable approach to control abnormal neural activities associated with psychiatric disorders and might consequently relief symptom severity. However, different aspects of neurofeedback remain unclear, such as its neural basis, the performance variation, the feedback effect, among others. Aim: First, we aimed to propose a functional near-infrared spectroscopy (fNIRS)-based affective neurofeedback based on the self-regulation of frontal and occipital networks. Second, we evaluated three different feedback approaches on performance: real, fixed, and random feedback. Third, we investigated different demographic, psychological, and physiological predictors of performance. Approach: Thirty-three healthy participants performed a task whereby an amorphous figure changed its shape according to the elicited affect (positive or neutral). During the task, the participants randomly received three different feedback

approaches: real feedback, with no change of the classifier output; fixed feedback, keeping the feedback figure unmodified; and random feedback, where the classifier output was multiplied by an arbitrary value, causing a feedback different than expected by the subject. Then, we applied a multivariate comparison of the whole-connectivity profiles according to the affective states and feedback approaches, as well as during a pretask resting-state block, to predict performance. Results: Participants were able to control this feedback system with 70.00 % 24.43 % ($p < 0.01$) of performance during the real feedback trials. No significant differences were found when comparing the average performances of the feedback approaches. However, the whole functional connectivity profiles presented significant Mahalanobis distances (p 0.001) when comparing both affective states and all feedback approaches. Finally, task performance was positively correlated to the pretask resting-state whole functional connectivity ($r = 0.512$, $p = 0.009$). Conclusions: Our results suggest that fNIRS might be a feasible tool to develop a neurofeedback system based on the self-regulation of affective networks. This finding enables future investigations using an fNIRS-based affective neurofeedback in psychiatric populations. Furthermore, functional connectivity profiles proved to be a good predictor of performance and suggested an increased effort to maintain task control in the presence of feedback distractors.

Neural Substrates of Cognitive Motor Interference During Walking; Peripheral and Central Mechanisms.

Al-Yahya E, Mahmoud W, Meester D, Esser P, Dawes H.

Front Hum Neurosci. Jan 9;12:
doi: 10.3389/fnhum.2018.eCollection 2018.

Current gait control models suggest that independent locomotion depends on central and peripheral mechanisms. However, less information is available on the integration of these mechanisms for adaptive walking. In this cross-sectional study, we investigated gait control mechanisms in people with Parkinson's disease (PD) and healthy older (HO) adults: at self-selected walking speed (SSWS) and at fast walking speed (FWS). We measured effect of additional cognitive task (DT) and increased speed on prefrontal (PFC) and motor cortex (M1) activation, and Soleus H-reflex gain. Under DT-conditions we observed increased activation in PFC and M1. Whilst H-reflex gain decreased with additional cognitive load for both groups and speeds, H-reflex gain was lower in PD compared to HO while

walking under ST condition at SSWS. Attentional load in PFC excites M1, which in turn increases inhibition on H-reflex activity during walking and reduces activity and sensitivity of peripheral reflex during the stance phase of gait. Importantly this effect on sensitivity was greater in HO. We have previously observed that the PFC copes with increased attentional load in young adults with no impact on peripheral reflexes and we suggest that gait instability in PD may in part be due to altered sensorimotor functioning reducing the sensitivity of peripheral reflexes.

Current Status and Issues Regarding Pre-processing of fNIRS Neuroimaging Data: An Investigation of Diverse Signal Filtering Methods Within a General Linear Model Framework.

Pinti P, Scholkmann F, Hamilton A, Burgess P, Tachtsidis I.

Front Hum Neurosci. Jan 11;12:
doi: 10.3389/fnhum.2018.00505. eCollection 2018.

Functional near-infrared spectroscopy (fNIRS) research articles show a large heterogeneity in the analysis approaches and pre-processing procedures. Additionally, there is often a lack of a complete description of the methods applied, necessary for study replication or for results comparison. The aims of this paper were (i) to review and investigate which information is generally included in published fNIRS papers, and (ii) to define a signal pre-processing procedure to set a common ground for standardization guidelines. To this goal, we have reviewed 110 fNIRS articles published in 2016 in the field of cognitive neuroscience, and performed a simulation analysis with synthetic fNIRS data to optimize the signal filtering step before applying the GLM method for statistical inference. Our results highlight the fact that many papers lack important information, and there is a large variability in the filtering methods used. Our simulations demonstrated that the optimal approach to remove noise and recover the hemodynamic response from fNIRS data in a GLM framework is to use a 1000th order band-pass Finite Impulse Response filter. Based on these results, we give preliminary recommendations as to the first step toward improving the analysis of fNIRS data and dissemination of the results.

Newborns are sensitive to multiple cues for word segmentation in continuous speech.

Fl A, Brusini P, Macagno F, Nespor M, Mehler J, Ferry AL.
Dev Sci. Jan 25:e
doi: 10.1111/desc.[Epub ahead of print]

Before infants can learn words, they must identify those words in continuous speech. Yet, the speech signal lacks obvious boundary markers, which poses a potential problem for language acquisition (Swingley, 2009). By the middle of the first year, infants seem to have solved this problem (Bergelson & Swingley, 2012; Jusczyk & Aslin, 1995), but it is unknown if segmentation abilities are present from birth, or if they only emerge after sufficient language exposure and/or brain maturation. Here, in two independent experiments, we looked at two cues known to be crucial for the segmentation of human speech: the computation of statistical co-occurrences between syllables and the use of the language's prosody. After a brief familiarization of about 3 minutes with continuous speech, using functional near-infrared spectroscopy (fNIRS), neonates showed differential brain responses on a recognition test to words that violated either the statistical (Experiment 1) or prosodic (Experiment 2) boundaries of the familiarization, compared to words that conformed to those boundaries. Importantly, word recognition in Experiment 2 occurred even in the absence of prosodic information at test, meaning that newborns encoded the phonological content independently of its prosody. These data indicate that humans are born with operational language processing and memory capacities and can use at least two types of cues to segment otherwise continuous speech, a key first step in language acquisition.

Towards the Neuromotor Control Processes of Steady-State and Speed-Matched Treadmill and Overground Walking.

Herold F, Aye N, Hamacher D, Schega L.
Brain Topogr. Jan
doi: 10.1007/s10548-019-00699-[Epub ahead of print]

The neuromotor control of walking relies on a network of subcortical and cortical structures. While kinematic differences between treadmill and overground walking are extensively studied, the neuromotor control processes are still relatively unknown. Hence, this study aims to investigate cortical activation during steady-state treadmill and overground walking using functional near-infrared spectroscopy, inertial measurement units and a heart rate monitor. We observed a higher concentration of oxygenated hemoglobin

in prefrontal cortices, premotor cortices and supplementary motor areas during treadmill walking. Therefore, our results suggest that treadmill walking requires higher demands on cortical neuromotor control.

Frequency-specific functional connectivity related to the rehabilitation task of stroke patients.

Lu K, Xu G, Li W, Huo C, Liu Q, Lv Z, Wang Y, Li Z, Fan Y.

Med Phys. Jan

doi: 10.1002/mp.[Epub ahead of print]

PURPOSES: Stroke survivors suffering from deficits in motor control typically show persistent motor symptoms and limited functional abilities, which affect their functional independence in daily life. Active rehabilitation training is commonly applied for stroke patients to recover from motor dysfunction. The global connectivity reflects the synchronization of cardiac and respiratory activities in the cerebral regions. However, the understanding of the patterns of frequency-specific global connectivity (GC) and functional connectivity (FC) when performing active rehabilitation training is still far from comprehensive. This study was conducted to investigate the brain network patterns of stroke patients while performing a four-limb linkage rehabilitation training using the functional near-infrared spectroscopy (fNIRS) method. METHODS: Two groups of stroke patients (LH, left hemiplegia; RH, right hemiplegia) and one healthy group were recruited to participate in this study. The wavelet phase coherence (WPCO) method was used to calculate the frequency-specific GC and FC of the brain network in four frequency bands: I, 0.6-2 Hz; II, 0.145-0.6 Hz; III, 0.052-0.145 Hz and IV, 0.021-0.052 Hz. RESULTS: Results showed that the healthy group exhibited lower WPCO in the four frequency bands during the task state than during the resting state ($p<0.05$). Interestingly, the stroke groups showed increased WPCO in the frequency band II during the task state than during the resting state ($p<0.05$). Moreover, significantly lower WPCO values in the frequency bands III ($p<0.05$) were found during task state in the RH and LH groups compared with the healthy group. The RH group showed increased WPCO values in the frequency band II during the task state compared with the healthy group ($p<0.05$). In addition, the RH group showed increased WPCO in the frequency bands I ($p<0.05$) and II ($p<0.05$) than the LH group. Notably, the rehabilitation task did not induce significant changes in stroke groups in the frequency band IV, which implied the neurogenic activity. CONCLUSIONS: The reductions in FC suggested that the

brain impairments caused a disturbed neurovascular coupling regulation in stroke patients. Results in frequency band IV suggested that the limb movement rehabilitation task intrinsically may not produce remarkable effect on the neurogenic activity of stroke patients. Significant differences in WPCO between the LH and RH groups suggested that the rehabilitation task should be specifically designed for individual rehabilitation. The frequency-specific FC methods based on WPCO would provide a potential approach to quantitatively assess the effect of rehabilitation tasks.

Cortical Network Response to Acupuncture and the Effect of the Hegu Point: An fNIRS Study.

Fernandez Rojas R, Liao M, Romero J, Huang X, Ou KL.

Sensors (Basel). Jan 18;19(2). pii: E
doi: 10.3390/s19020394.

Acupuncture is a practice of treatment based on influencing specific points on the body by inserting needles. According to traditional Chinese medicine, the aim of acupuncture treatment for pain management is to use specific acupoints to relieve excess, activate qi (or vital energy), and improve blood circulation. In this context, the Hegu point is one of the most widely-used acupoints for this purpose, and it has been linked to having an analgesic effect. However, there exists considerable debate as to its scientific validity. In this pilot study, we aim to identify the functional connectivity related to the three main types of acupuncture manipulations and also identify an analgesic effect based on the hemodynamic response as measured by functional near-infrared spectroscopy (fNIRS). The cortical response of eleven healthy subjects was obtained using fNIRS during an acupuncture procedure. A multiscale analysis based on wavelet transform coherence was employed to assess the functional connectivity of corresponding channel pairs within the left and right somatosensory region. The wavelet analysis was focused on the very-low frequency oscillations (VLFO, 0.01?0.08 Hz) and the low frequency oscillations (LFO, 0.08?0.15 Hz). A mixed model analysis of variance was used to appraise statistical differences in the wavelet domain for the different acupuncture stimuli. The hemodynamic response after the acupuncture manipulations exhibited strong activations and distinctive cortical networks in each stimulus. The results of the statistical analysis showed significant differences ($p < 0.05$) between the tasks in both frequency bands. These results suggest the existence of different stimuli-specific cortical networks

in both frequency bands and the anaesthetic effect of the Hegu point as measured by fNIRS.

Probing prefrontal cortex hemodynamic alterations during facial emotion recognition for major depression disorder through functional near-infrared spectroscopy.

Gao L, Cai Y, Wang H, Wang G, Zhang Q, Yan X.

J Neural Eng. Jan

doi: 10.1088/1741-2552/ab[Epub ahead of print]

OBJECTIVE: A serious issue in psychiatric practice is a lack of specific, objective biomarker to assist clinicians in establishing differential diagnosis and improving individualized treatment. Major depression disorder (MDD) is characterized by poorer ability in processing of facial emotional expressions. APPROACH: Applying a portable neuroimaging system using near-infrared spectroscopy, we investigated the prefrontal cortex hemodynamic activation changes during facial emotion recognition and rest periods for 27 MDD patients compared with 24 healthy controls (HC). MAIN RESULTS: The hemodynamic changes in the left prefrontal cortex for the MDD group showed significant differences in the median values and the Mayer wave power ratios of the oxygenated hemoglobin (oxy-Hb) and deoxygenated hemoglobin (deoxy-Hb) during the emotional face recognition compared with the HC subjects, indicating the abnormal oxidative metabolism and weaker local hemodynamic oscillations for the MDD. The mean cross wavelet coefficients and the average wavelet coherence coefficient between oxy-Hb and deoxy-Hb over the left prefrontal cortex, and also between the bilateral oxy-Hb in the MDD patients were significantly lower than the HC group, demonstrating abnormal locally functional connectivity over the left prefrontal cortex, and the inter-hemispheric connection between the bilateral prefrontal cortices. SIGNIFICANCE: These results suggested that the hemodynamic changes over the left prefrontal cortex and between the bilateral prefrontal cortices detected by fNIRS could provide reliable predictors for the diagnosis of the depression in clinic, and also supported the rationale for use of transcranial magnetic stimulation over the left dorsolateral prefrontal cortex to restore excitability of prefrontal cortex that exhibits diminished regulation of emotion-generative systems in the MDD patients.

Exploring brain functions in autism spectrum disorder: A systematic review on functional near-infrared spectroscopy (fNIRS) studies.

Zhang F, Roeyers H.

Int J Psychophysiol. Mar;137:41-
doi: 10.1016/j.ijpsycho.2019.01.003. Epub Jan 19.

A growing body of research has investigated the functional development of the brain in autism spectrum disorder (ASD). Functional near-infrared spectroscopy (fNIRS) is increasingly being used in this respect. This method has several advantages over other functional neuroimaging techniques in studying brain functions in ASD, including portability, low cost, and availability in naturalistic settings. This article reviews thirty empirical studies, published in the past decade, that used fNIRS in individuals with ASD or in infants with a high risk of developing ASD. These studies investigated either brain activation using multiple tasks (e.g., face processing, joint attention and working memory) or functional organization under a resting-state condition in ASD. The majority of these studies reported atypical brain activation in the prefrontal cortex, inferior frontal gyrus, middle and superior temporal gyrus. Some studies revealed altered functional connectivity, suggesting an inefficient information transfer between brain regions in ASD. Overall, the findings suggest that fNIRS is a promising tool to explore neurodevelopment in ASD from an early age.

Denoising of neuronal signal from mixed systemic low-frequency oscillation using peripheral measurement as noise regressor in near-infrared imaging.

Sutoko S, Chan YL, Obata A, Sato H, Maki A, Numata T, Funane T, Atsumori H, Kiguchi M, Tang TB, Li Y, Frederick BD, Tong Y.

Neurophotonics. Jan;6(1):
doi: 10.1117/1.NPh.6.1.Epub 2019 Jan 9.

Functional near-infrared spectroscopy (fNIRS) is a noninvasive functional imaging technique measuring hemodynamic changes including oxygenated (O 2 Hb) and deoxygenated (HHb) hemoglobin. Low frequency (LF; 0.01 to 0.15Hz) band is commonly analyzed in fNIRS to represent neuronal activation. However, systemic physiological artifacts (i.e., non-neuronal) likely occur also in overlapping frequency bands. We measured peripheral photoplethysmogram (PPG) signal concurrently with fNIRS (at prefrontal region) to extract the low-frequency oscillations (LFOs) as sys-

temic noise regressors. We investigated three main points in this study: (1)the relationship between prefrontal fNIRS and peripheral PPG signals; (2)the denoising potential using these peripheral LFOs, and (3)the innovative ways to avoid the false-positive result in fNIRS studies. We employed spatial working memory (WM) and control tasks (e.g., resting state) to illustrate these points. Our results showed: (1)correlation between signals from prefrontal fNIRS and peripheral PPG is region-dependent. The high correlation with peripheral ear signal (i.e., O 2 Hb) occurred mainly in frontopolar regions in both spatial WM and control tasks. This may indicate the finding of task-dependent effect even in peripheral signals. We also found that the PPG recording at the ear has a high correlation with prefrontal fNIRS signal than the finger signals. (2)The systemic noise was reduced by 25% to 34% on average across regions, with a maximum of 39% to 58% in the highly correlated frontopolar region, by using these peripheral LFOs as noise regressors. (3)By performing the control tasks, we confirmed that the statistically significant activation was observed in the spatial WM task, not in the controls. This suggested that systemic (and any other) noises unlikely violated the major statistical inference. (4)Lastly, by denoising using the task-related signals, the significant activation of region-of-interest was still observed suggesting the manifest task-evoked response in the spatial WM task.

The Use of Functional Near-Infrared Spectroscopy to Differentiate Alcohol-Related Neurodevelopmental Impairment.

Barrett CE, Kable JA, Madsen TE, Hsu CC, Coles CD.

Dev Neuropsychol. Jan 20:1-
doi: 10.1080/87565641.2019.[Epub ahead of print]

Oxygenated (HBO) and deoxygenated hemoglobin (HBR) levels in the prefrontal cortex (PFC) were measured using functional near-infrared spectroscopy (fNIRS) to determine if PFC activity during a cognitive inhibition task distinguishes children with prenatal alcohol exposure (PAE, n =26) from both typically developing controls (n =19) and a contrast group of children with other neurobehavioral problems (n =14). Despite showing evidence of increased PFC activity in the non-inhibitory condition relative to controls, children in the PAE group displayed reduced PFC HBO and increased HBR relative to both other groups in the inhibitory condition, suggesting reduced PFC activity but increased oxygen consumption without sufficient oxygen replacement.

Aging effects on prefrontal cortex oxygenation in a posture-cognition dual-task: an fNIRS pilot study.

Marusic U, Taube W, Morrison SA, Biasutti L, Grassi B, De Pauw K, Meeusen R, Pisot R, Ruffieux J.

Eur Rev Aging Phys Act. Jan 11;16:
doi: 10.1186/s11556-018-0209-7. eCollection 2019.

Background: The aging process alters upright posture and locomotion control from an automatically processed to a more cortically controlled one. The present study investigated a postural-cognitive dual-task paradigm in young and older adults using functional Near-Infrared Spectroscopy (fNIRS). Methods: Twenty healthy participants (10 older adults 72??3 y, 10 young adults 23??3 y) performed a cognitive (serial subtractions) and a postural task (tandem stance) as single-tasks (ST) and concurrently as a dual-task (DT) while the oxygenation levels of the dorsolateral prefrontal cortex (DLPFC) were measured. Results: In the cognitive task, young adults performed better than older adults in both conditions (ST and DT) and could further increase the number of correct answers from ST to DT (all ps?=?0.027) while no change was found for older adults. No significant effects were found for the postural performance. Cerebral oxygenation values (O2Hb) increased significantly from baseline to the postural ST (p?=?0.033), and from baseline to the DT (p?=?0.031) whereas no changes were found in deoxygenated hemoglobin (HHb). Finally, the perceived exertion differed between all conditions (p?=?0.003) except for the postural ST and the DT (p?=?0.204). Conclusions: There was a general lack of age-related changes except the better cognitive performance under motor-cognitive conditions in young compared to older adults. However, the current results point out that DLPFC is influenced more strongly by postural than cognitive load. Future studies should assess the different modalities of cognitive as well as postural load.

A Review on the Use of Wearable Functional Near-Infrared Spectroscopy in Naturalistic Environments.

Pinti P, Aichelburg C, Gilbert S, Hamilton A, Hirsch J, Burgess P, Tachtsidis I.

Jpn Psychol Res. Oct;60(4):347-
doi: 10.1111/jpr.Epub Jul 19.

The development of novel miniaturized wireless and wearable functional Near-Infrared Spectroscopy (fNIRS) devices have paved the way to new functional brain imaging that can revolutionize the cognitive research fields. Over the past few decades, several studies have been conducted with conventional fNIRS systems that have demonstrated the suitability of this technology for a wide variety of populations and applications, to investigate both the healthy brain and the diseased brain. However, what makes wearable fNIRS even more appealing is its capability to allow measurements in everyday life scenarios that are not possible with other gold-standard neuroimaging modalities, such as functional Magnetic Resonance Imaging. This can have a huge impact on the way we explore the neural bases and mechanisms underpinning human brain functioning. The aim of this review is to provide an overview of studies conducted with wearable fNIRS in naturalistic settings in the field of cognitive neuroscience. In addition, we present the challenges associated with the use of wearable fNIRS in unrestrained contexts, discussing solutions that will allow accurate inference of functional brain activity. Finally, we provide an overview of the future perspectives in cognitive neuroscience that we believe would benefit the most by using wearable fNIRS.

Classification of motor imagery and execution signals with population-level feature sets: Implications for probe design in fNIRS based BCI.

Erdogan SB, zsarfati E, Dilek B, Sogukkanli Kadak K, Hanoglu L, Akin A.
J Neural Eng. Jan
doi: 10.1088/1741-2552/aafdca. [Epub ahead of print]

OBJECTIVE: The aim of this study was to introduce a novel methodology for classification of brain hemodynamic responses collected via functional near infrared spectroscopy (fNIRS) during rest, motor imagery (MI) and motor execution (ME) tasks which involves generating population-level training sets. Main Approach: A 48 channel fNIRS system was utilized to obtain hemodynamic signals from the frontal (FC), primary motor (PMC) and somatosensory cortex (SMC) of 10 subjects during an experimental paradigm consisting of ME and MI of various right hand movements. Classification accuracies of random forest (RF), support vector machines (SVM), and artificial neural networks (ANN) were computed at the single subject level by training each classifier with subject specific features, and at the group level by training with features from all subjects for ME vs. Rest,

MI vs. Rest and MI vs. ME conditions. The performances were also computed for channel data restricted to FC, PMC and SMC regions separately to determine optimal probe location. RESULTS: RF, SVM and ANN had comparably high classification accuracies for ME vs. Rest (%94, %96 and % 98 respectively) and for MI vs.Rest (%95, %95 and % 98 respectively) when fed with group level feature sets. The accuracy performance of each algorithm in localized brain regions were comparable (>%93) to the accuracy performance obtained with whole brain channels (>%94) for both ME vs. Rest and MI vs. Rest conditions. SIGNIFICANCE: By demonstrating the feasibility of generating a population level training set with a high classification performance for 3 different classification algorithms, the findings pave the path for removing the necessity to acquire subject specific training data and hold promise for a novel, real-time fNIRS based BCI system design which will be most effective for application to disease populations for whom obtaining data to train a classification algorithm is not possible.

Praising or keeping silent on partner's ideas: Leading brainstorming in particular ways.

Lu K, Qiao X, Hao N.

Neuropsychologia. Feb 18;124:19-
doi: 10.1016/j.neuropsychologia.2019.01.Epub Jan 8.

This study aimed to investigate how different feedback affect group creative performance, and reveal the underlying interpersonal neural correlates using the functional near-infrared spectroscopy (fNIRS)-based hyperscanning technique. Participants solved one creativity task with two strangers in conditions with positive/negative/no feedback. Results revealed that performance in the negative condition was lower than in the other conditions. Moreover, results showed the highest 'index of convergence'/collective flexibility in the positive/control condition respectively. The fNIRS results demonstrated IBS increment in the frontopolar and bilateral dorsolateral prefrontal cortex, which was stronger in the positive and negative conditions. The IBS increment in the frontopolar and bilateral DLPFC covaried with group creative performance in the positive condition. The findings indicated that negative feedback suppressed the group creative performance; whereas no feedback facilitated collective flexibility and positive feedback promoted interpersonal interaction, these two feedback conditions both benefited group creative performance.

Comparison of source localization techniques in diffuse optical tomography for fNIRS application using a realistic head model.

Tremblay J, Martnez-Montes E, Vannasing P, Nguyen DK, Sawan M, Lepore F, Gallagher A.

Biomed Opt Express. Jun 7;9(7):2994-
doi: 10.1364/BOE.9.002994. eCollection Jul 1.

Functional near-infrared spectroscopy (fNIRS) is a non-invasive imaging technique that elicits growing interest for research and clinical applications. In the last decade, efforts have been made to develop a mathematical framework in order to image the effective sources of hemoglobin variations in brain tissues. Different approaches can be used to impose additional information or constraints when reconstructing the cerebral images of an ill-posed problem. The goal of this study is to compare the performance and limitations of several source localization techniques in the context of fNIRS tomography using individual anatomical magnetic resonance imaging (MRI) to model light propagation. The forward problem is solved using a Monte Carlo simulation of light propagation in the tissues. The inverse problem has been linearized using the Rytov approximation. Then, Tikhonov regularization applied to least squares, truncated singular value decomposition, back-projection, L1-norm regularization, minimum norm estimates, low resolution electromagnetic tomography and Bayesian model averaging techniques are compared using a receiver operating characteristic analysis, blurring and localization error measures. Using realistic simulations (n = 450) and data acquired from a human participant, this study depicts how these source localization techniques behave in a human head fNIRS tomography. When compared to other methods, Bayesian model averaging is proposed as a promising method in DOT and shows great potential to improve specificity, accuracy, as well as to reduce blurring and localization error even in presence of noise and deep sources. Classical reconstruction methods, such as regularized least squares, offer better sensitivity but higher blurring; while more novel L1-based method provides sparse solutions with small blurring and high specificity but lower sensitivity. The application of these methods is also demonstrated experimentally using visual fNIRS experiment with adult participant.

Initial-Dip Existence and Estimation in Relation to DPF and Data Drift.

Kamran MA, Naeem Mannan MM, Jeong MY.

Front Neuroinform. Dec 11;12:
doi: 10.3389/fninf.2018.eCollection 2018.

Early de-oxygenation (initial dip) is an indicator of the primal cortical activity source in functional neuro-imaging. In this study, initial dip's existence and its estimation in relation to the differential pathlength factor (DPF) and data drift were investigated in detail. An efficient algorithm for estimation of drift in fNIRS data is proposed. The results favor the shifting of the fNIRS signal to a transformed coordinate system to infer correct information. Additionally, in this study, the effect of the DPF on initial dip was comprehensively analyzed. Four different cases of initial dip existence were treated, and the resultant characteristics of the hemodynamic response function (HRF) for DPF variation corresponding to particular near-infrared (NIR) wavelengths were summarized. A unique neuro-activation model and its iterative optimization solution that can estimate drift in fNIRS data and determine the best possible fit of HRF with free parameters were developed and herein proposed. The results were verified on simulated data sets. The algorithm is applied to free available datasets in addition to six healthy subjects those were experimented using fNIRS and observations and analysis regarding shape of HRF were summarized as well. A comparison with standard GLM is also discussed and effects of activity strength parameters have also been analyzed.

The Role of Premotor Areas in Dual Tasking in Healthy Controls and Persons With Multiple Sclerosis: An fNIRS Imaging Study.

Saleh S, Sandroff BM, Vitiello T, Owoeye O, Hoxha A, Hake P, Goverover Y, Wylie G, Yue G, DeLuca J.

Front Behav Neurosci. Dec 11;12:
doi: 10.3389/fnbeh.2018.00296. eCollection 2018.

Persons with multiple sclerosis (pwMS) experience declines in physical and cognitive abilities and are challenged by dual-tasks. Dual-tasking causes a drop in performance, or what is known as dual-task cost (DTC). This study examined DTC of walking speed (WS) and cognitive performance (CP) in pwMS and healthy controls (HCs) and the effect of dual-tasking on cortical activation of bilateral premotor cortices (PMC) and bilateral sup-

plementary motor area (SMA). Fourteen pwMS and 14 HCs performed three experimental tasks: (1) single cognitive task while standing (SingCog); (2) single walking task (SingWalk); and (3) dual-task (DualT) that included concurrent performance of the SingCog and SingWalk. Six trials were collected for each condition and included measures of cortical activation, WS and CP. WS of pwMS was significantly lower than HC, but neuropsychological (NP) measures were not significantly different. pwMS and HC groups had similar DTC of WS, while DTC of CP was only significant in the MS group; processing speed and visual memory predicted 55% of this DTC. DualT vs. SingWalk recruited more right-PMC activation only in HCs and was associated with better processing speed. DualT vs. SingCog recruited more right-PMC activation and bilateral-SMA activation in both HC and pwMS. Lower baseline WS and worse processing speed measures in pwMS predicted higher recruitment of right-SMA (rSMA) activation suggesting maladaptive recruitment. Lack of significant difference in NP measures between groups does not rule out the influence of cognitive factors on dual-tasking performance and cortical activations in pwMS, which might have a negative impact on quality of life.

Making social neuroscience less WEIRD: Using fNIRS to measure neural signatures of persuasive influence in a Middle East participant sample.

Burns SM, Barnes LN, McCulloh IA, Dagher MM, Falk EB, Storey JD, Lieberman MD.

J Pers Soc Psychol. Jan
doi: 10.1037/pspa[Epub ahead of print]

The large majority of social neuroscience research uses WEIRD populations-participants from Western, educated, industrialized, rich, and democratic locations. This makes it difficult to claim whether neuropsychological functions are universal or culture specific. In this study, we demonstrate one approach to addressing the imbalance by using portable neuroscience equipment in a study of persuasion conducted in Jordan with an Arabic-speaking sample. Participants were shown persuasive videos on various health and safety topics while their brain activity was measured using functional near infrared spectroscopy (fNIRS). Self-reported persuasiveness ratings for each video were then recorded. Consistent with previous research conducted with American subjects, this work found that activity in the dorsomedial and ventromedial prefrontal cortex predicted how persuasive participants found the

videos and how much they intended to engage in the messages' endorsed behaviors. Further, activity in the left ventrolateral prefrontal cortex was associated with persuasiveness ratings, but only in participants for whom the message was personally relevant. Implications for these results on the understanding of the brain basis of persuasion and on future directions for neuroimaging in diverse populations are discussed.

Corrigendum: Assessing the Driver's Current Level of Working Memory Load With High Density Functional Near-infrared Spectroscopy: A Realistic Driving Simulator Study.

Unni A, Ihme K, Jipp M, Rieger J.

Front Hum Neurosci. Dec 18;12:
doi: 10.3389/fnhum.2018.00498. eCollection 2018.

Erratum for Front Hum Neurosci. 2017 Apr 05;11:167.

Human central auditory plasticity: A review of functional near-infrared spectroscopy (fNIRS) to measure cochlear implant performance and tinnitus perception.

Basura GJ, Hu XS, Juan JS, Tessier AM, Kovelman I.

Laryngoscope Investig Otolaryngol. Oct 18;3(6):463-
doi: 10.1002/lio2.eCollection Dec.

Objective: Functional near-infrared spectroscopy (fNIRS) is an emerging noninvasive technology used to study cerebral cortex activity. Being virtually silent and compatible with cochlear implants has helped establish fNIRS as an important tool when investigating auditory cortex as well as cortices involved with hearing and language processing in adults and during child development. With respect to this review article, more recently, fNIRS has also been used to investigate central auditory plasticity following hearing loss and tinnitus or phantom sound perception. Methods: Here, we review the currently available literature reporting the use of fNIRS in human studies with cochlear implants and tinnitus to measure human central auditory cortical circuits. We also provide the reader with detailed reviews of the technology and traditional recording paradigms/methods used in these auditory-based studies. Results: The purpose of this review article is to summarize theoretical advancements in our understanding of the neurocognitive mechanisms

underlying auditory processes and their plasticity through fNIRS research of human auditory performance with cochlear implantation and plasticity that may contribute to the central percepts of tinnitus. Conclusion: fNIRS is an emerging noninvasive brain imaging technology that has wide reaching application that can be applied to human studies involving cochlear implants and tinnitus. Level of Evidence: N/A.

Evaluation of Sheep Anticipatory Response to a Food Reward by Means of Functional Near-Infrared Spectroscopy.

Chincarini M, Qiu L, Spinelli L, Torricelli A, Minero M, Dalla Costa E, Mariscoli M, Ferri N, Giammarco M, Vignola G.

Animals (Basel). Dec 29;9(1). pii: E
doi: 10.3390/ani9010011.

Anticipatory behaviour to an oncoming food reward can be triggered via classical conditioning, implies the activation of neural networks, and may serve to study the emotional state of animals. The aim of this study was to investigate how the anticipatory response to a food reward affects the cerebral cortex activity in sheep. Eight ewes from the same flock were trained to associate a neutral auditory stimulus (water bubble) to the presence of a food reward (maize grains). Once conditioned, sheep were trained to wait 15 s behind a gate before accessing a bucket with food (anticipation phase). For 6 days, sheep were submitted to two sessions of six consecutive trials each. Behavioural reaction was filmed and changes in cortical oxy- and deoxy-hemoglobin concentration ([?O2Hb] and [?HHb] respectively) following neuronal activation were recorded by functional near infrared spectroscopy (fNIRS). Compared to baseline, during the anticipation phase sheep increased their active behaviour, kept the head oriented to the gate (Wilcoxon's signed rank test; $p = 0.001$), and showed more asymmetric ear posture (Wilcoxon's signed rank test; $p = 0.01$), most likely reflecting a learnt association and an increased arousal. Results of trial-averaged [?O2Hb] and [?HHb] within individual sheep showed in almost every sheep a cortical activation during the anticipation phase (Student T-test; $p = 0.05$). The sheep showed a greater response of the right hemisphere compared to the left hemisphere, possibly indicating a negative affective state, such as frustration. Behavioural and cortical changes observed during anticipation of a food reward reflect a learnt association and an increased arousal, but no clear emotional valence of the sheep subjective experience. Future work should take into consideration possible factors affecting the accurateness of

measures, such as probe's location and scalp vascularization.

Inter-brain synchrony in mother-child dyads during cooperation: An fNIRS hyperscanning study.

Miller JG, Vrticka P, Cui X, Shrestha S, Hosseini SMH, Baker JM, Reiss AL.

Neuropsychologia. Feb 18;124:117-
doi: 10.1016/j.neuropsychologia.2018.12.Epub Dec 27.

Coordinated brain activity between individuals, or inter-brain synchrony, has been shown to increase during cooperation and correlate with cooperation success. However, few studies have examined parent-child inter-brain synchrony and whether it is associated with meaningful aspects of the parent-child relationship. Here, we measured inter-brain synchrony in the right prefrontal (PFC) and temporal cortices in mother-child dyads while they engaged in a cooperative and independent task. We tested whether inter-brain synchrony in mother-child dyads (1) increases during cooperation, (2) differs in mother-son versus mother-daughter dyads, and (3) is related to cooperation performance and the attachment relationship. Overall inter-brain synchrony in the right hemisphere, and the right dorsolateral and frontopolar PFC in particular, was higher during cooperation. Mother-son dyads showed less inter-brain synchrony during the independent task and a stronger increase in synchrony in response to cooperation than mother-daughter dyads. Lastly, we did not find strong evidence for links between inter-brain synchrony and child attachment. Mother-child cooperation may increase overall inter-brain synchrony, although differently for mother-son versus mother-daughter dyads. More research is needed to better understand the potential role of overall inter-brain synchrony in mother-child cooperation, and the potential link between inter-brain synchrony and attachment.

A novel motor imagery hybrid brain computer interface using EEG and functional transcranial Doppler ultrasound.

Khalaf A, Sejdic E, Akcakaya M.

J Neurosci Methods. Feb 1;313:44-
doi: 10.1016/j.jneumeth.2018.11.017. Epub Dec 24.

BACKGROUND: Hybrid brain computer interfaces (BCIs) combining multiple brain imaging modalities have been proposed recently to boost the

performance of single modality BCIs. NEW METHOD: In this paper, we propose a novel motor imagery (MI) hybrid BCI that uses electrical brain activity recorded using Electroencephalography (EEG) as well as cerebral blood flow velocity measured using functional transcranial Doppler ultrasound (fTCD). Features derived from the power spectrum for both EEG and fTCD signals were calculated. Mutual information and linear support vector machines (SVM) were employed for feature selection and classification. RESULTS: Using the EEG-fTCD combination, average accuracies of 88.33%, 89.48%, and 82.38% were achieved for right arm MI versus baseline, left arm MI versus baseline, and right arm MI versus left arm MI respectively. Compared to performance measures obtained using EEG only, the hybrid system provided significant improvement in terms of accuracy by 4.48%, 5.36%, and 4.76% respectively. In addition, average transmission rates of 4.17, 5.45, and 10.57 bits/min were achieved for right arm MI versus baseline, left arm MI versus baseline, and right arm MI versus left arm MI respectively. COMPARISON WITH EXISTING METHODS: Compared to EEG-fNIRS hybrid BCIs in literature, we achieved similar or higher accuracies with shorter task duration. CONCLUSIONS: The proposed hybrid system is a promising candidate for real-time BCI applications.

Functional near-infrared spectroscopy as a tool for assessing speech and spoken language processing in pediatric and adult cochlear implant users.

Bortfeld H.

Dev Psychobiol. Dec

doi: 10.1002/dev.[Epub ahead of print]

Much of what is known about the course of auditory learning in following cochlear implantation is based on behavioral indicators that users are able to perceive sound. Both prelingually deafened children and postlingually deafened adults who receive cochlear implants display highly variable speech and language processing outcomes, although the basis for this is poorly understood. To date, measuring neural activity within the auditory cortex of implant recipients of all ages has been challenging, primarily because the use of traditional neuroimaging techniques is limited by the implant itself. Functional near-infrared spectroscopy (fNIRS) is an imaging technology that works with implant users of all ages because it is non-invasive, compatible with implant devices, and not subject to electrical artifacts. Thus, fNIRS can provide insight into processing factors that contribute to variations in

spoken language outcomes in implant users, both children and adults. There are important considerations to be made when using fNIRS, particularly with children, to maximize the signal-to-noise ratio and to best identify and interpret cortical responses. This review considers these issues, recent data, and future directions for using fNIRS as a tool to understand spoken language processing in children and adults who hear through a cochlear implant.

A novel phase analysis method for examining fNIRS neuroimaging data associated with Chinese/English sight translation.

Ren H, Wang MY, He Y, Du Z, Zhang J, Zhang J, Li D, Yuan Z.

Behav Brain Res. Apr 1;361:151-
doi: 10.1016/j.bbr.2018.12.Epub Dec 18.

In this study, a phase method for analyzing functional near-infrared spectroscopy (fNIRS) signals was developed, which can extract the phase information of fNIRS data by using Hilbert transform. More importantly, the phase analysis method can be further performed to generate the brain phase activation and to construct the brain networks. Meanwhile, the study of translation between Chinese and English has been exciting and interesting from both the language and neuroscience standpoints due to their drastically different linguistic features. In particular, inspecting the brain phase activation and functional connectivity based on the phase data and phase analysis method will enable us to better understand the neural mechanism associated with Chinese/English translation. Our phase analysis results showed that the left prefrontal cortex, including the dorsolateral prefrontal cortex (DLPFC) and frontopolar area, was involved in the translation process of the language pair. In addition, we also discovered that the most significant brain phase activation difference between translating into non-native (English) vs. native (Chinese) language was identified in the Broca's area. As a result, the proposed phase analysis approach can provide us an additional tool to reveal the complex cognitive mechanism associated with Chinese/English sight translation.

Validating attentive locomotion training using interactive treadmill: an fNIRS study.

Oh S, Song M, Kim J.
J Neuroeng Rehabil. Dec 20;15(1):
doi: 10.1186/s12984-018-0472-x.

BACKGROUND: Existing treadmill-based locomotion training, which has been used for gait function recovery, still has limitations, such as less attentive training. Interactive treadmills (ITMs) were developed to overcome these limitations, but it has not yet been verified that ITMs can make the user pay closer attention to walk training. METHODS: An experimental comparison between ITMs and conventional treadmills was conducted by measuring the level of the user's attention using functional near-infrared spectroscopy (fNIRS). To consider the effect of task complexity on the subject's attention, we provided two (slow and fast) speed conditions for walking on both treadmills. RESULTS: Both the cortical activity images and oxygenated hemoglobin (oxyHb) changes showed that the level of attention to walking induced by the ITM was significantly higher than that induced by the conventional treadmill. We found that the walking speed on the ITM also affected the level of attention. CONCLUSION: ITM-based locomotion training would be a promising solution to the limitations of existing treadmill-based locomotion training currently used to improve gait function recovery. TRIAL REGISTRATION: DGIST-HR-150309-03-02 . Registered 01 March 2015.

The Utility of fNIRS for Measuring Cortical Activity during Cycling-Exercise.

Tempest GD, Reiss AL.
Med Sci Sports Exerc. Dec
doi: 10.1249/MSS.[Epub ahead of print]

PURPOSE: Real-time measurement of dynamic brain activity during exercise can help advance our understanding of the role of exercise upon brain health and function. In exercise science, functional near infrared spectroscopy (fNIRS) has primarily been used to measure the effects of exercise intensity upon hemodynamic responses in the cerebral cortex. However, the utility of fNIRS to measure discreet hemodynamic responses underlying brain activation associated with motor and cognitive function during exercise has not been systematically examined. Here, we compared brain activation associated with a motor and cognitive task at rest and during cycling-exercise at different intensities. METHODS: In separate sessions, 13 participants performed cycling-exercise on an indoor trainer at a low,

moderate and high intensity. We measured changes in oxygenated (HbO) and deoxygenated (HbR) hemoglobin from prefrontal, parietal and motor regions of the cerebral cortex during a handgrip and working-memory task. RESULTS: Our findings show significant brain activation (a concurrent increase in HbO and decrease in HbR) in contralateral motor cortex during the handgrip task and left prefrontal cortex during the working-memory task at rest and during exercise at low, moderate and high (motor task HbO only) intensities ($P < .05$). Moreover, brain activation during the handgrip and working-memory tasks was not significantly different at rest and during exercise ($P > .05$). CONCLUSIONS: This study shows that fNIRS can robustly measure motor and cognitive task-evoked changes in brain activation during cycling-exercise comparable to rest. An implication of these new findings is that fNIRS can be used to determine real-time changes in brain function during exercise in healthy and clinical populations.

Effective connectivity in subjects with mild cognitive impairment as assessed using functional near-infrared spectroscopy.
Bu L, Huo C, Qin Y, Xu G, Wang Y, Li Z.
Am J Phys Med Rehabil. Dec
doi: 10.1097/PHM.[Epub ahead of print]

OBJECTIVE: This study aimed to reveal the physiological mechanism in subjects with mild cognitive impairment (MCI) based on effective connectivity (EC) method. METHODS: EC was assessed by dynamic Bayesian inference (DBI) of the oxygenated hemoglobin concentration (?[HbO2]) signals measured through functional near-infrared spectroscopy (fNIRS). The ?[HbO2] signals were recorded from the left prefrontal cortex (LPFC), right prefrontal cortex (RPFC), left motor cortex (LMC), right motor cortex (RMC), left occipital lobe (LOL) and right occipital lobe (ROL) of 26 subjects with MCI (MCI group) and 28 healthy elderly subjects (control group) at resting state. RESULTS: The coupling strength (CS) of RPFC to LPFC ($F = 7.964$, $p = 0.007$) and LPFC to ROL ($F = 4.278$, $p = 0.044$) in interval III, and LPFC to LOL ($F = 5.637$, $p = 0.021$), ROL to LPFC ($F = 4.762$, $p = 0.034$) and RPFC to LOL ($F = 4.06$, $p = 0.049$) in interval IV in the MCI group were significantly lower than those in the control group. CONCLUSIONS: The decreased EC levels among brain regions may be a marker of impaired cognitive function in the MCI group. The constructed EC network based on fNIRS provide a non-invasive method to assess MCI.

Transcranial Direct Current Stimulation Does Not Counteract Cognitive Fatigue, but Induces Sleepiness and an Inter-Hemispheric Shift in Brain Oxygenation.

Borragn G, Gilson M, Guerrero-Mosquera C, Di Ricci E, Slama H, Peigneux P.

Front Psychol. Nov 30;9:
doi: 10.3389/fpsyg.2018.eCollection 2018.

Sustained cognitive demands may result in cognitive fatigue (CF), eventually leading to decreased behavioral performance and compromised brain resources. In the present study, we tested the hypothesis that transcranial direct current stimulation (tDCS) would counteract the behavioral and neurophysiological effects of CF. Twenty young healthy participants were tested in a within-subject counterbalanced order across two different days. Anodal tDCS (real vs. sham) was applied over the left prefrontal cortex. In the real tDCS condition, a current of 1.5 mA was delivered for 25 min. Cortical oxygenation changes were measured using functional Near Infrared Spectroscopy (fNIRS) on the frontal cortices. CF was triggered using the TloadDback task, a sustained working memory paradigm that allows tailoring task demands according to each individual's maximal cognitive capacity. Sustained cognitive load-related effects were assessed using pre- versus post-task subjective fatigue and sleepiness scales, evolution of performance accuracy within the task, indirect markers of dopaminergic activity (eye blinks), and cortical oxygenation changes (fNIRS) both during the task and pre- and post-task resting state periods. Results consistently disclosed significant CF-related effects on performance. Transcranial DCS was not effective to counteract the behavioral effects of CF. In the control (sham tDCS) condition, cerebral oxygen exchange (COE) levels significantly increased in the right hemisphere during the resting state immediately after the induction of CF, suggesting a depletion of brain resources. In contrast, tDCS combined with CF induction significantly shifted interhemispheric oxygenation balance during the post-training resting state. Additionally, increased self-reported sleepiness was associated with brain activity in the stimulated hemisphere after recovery from CF during the tDCS condition only, which might reflect a negative middle-term effect of tDCS application.

Multifractal Dynamic Functional Connectivity in the Resting-

State Brain.

Racz FS, Stylianou O, Mukli P, Eke A.

Front Physiol. Nov 30;9:
doi: 10.3389/fphys.2018.eCollection 2018.

Assessing the functional connectivity (FC) of the brain has proven valuable in enhancing our understanding of brain function. Recent developments in the field demonstrated that FC fluctuates even in the resting state, which has not been taken into account by the widely applied static approaches introduced earlier. In a recent study using functional near-infrared spectroscopy (fNIRS) global dynamic functional connectivity (DFC) has also been found to fluctuate according to scale-free i.e., fractal dynamics evidencing the true multifractal (MF) nature of DFC in the human prefrontal cortex. Expanding on these findings, we performed electroencephalography (EEG) measurements in 14 regions over the whole cortex of 24 healthy, young adult subjects in eyes open (EO) and eyes closed (EC) states. We applied dynamic graph theoretical analysis to capture DFC by computing the pairwise time-dependent synchronization between brain regions and subsequently calculating the following dynamic graph topological measures: Density, Clustering Coefficient, and Efficiency. We characterized the dynamic nature of these global network metrics as well as local individual connections in the networks using focus-based multifractal time series analysis in all traditional EEG frequency bands. Global network topological measures were found fluctuating-albeit at different extent-according to true multifractal nature in all frequency bands. Moreover, the monofractal Hurst exponent was found higher during EC than EO in the alpha and beta bands. Individual connections showed a characteristic topology in their fractal properties, with higher autocorrelation owing to short-distance connections-especially those in the frontal and pre-frontal cortex-while long-distance connections linking the occipital to the frontal and pre-frontal areas expressed lower values. The same topology was found with connection-wise multifractality in all but delta band connections, where the very opposite pattern appeared. This resulted in a positive correlation between global autocorrelation and connection-wise multifractality in the higher frequency bands, while a strong anticorrelation in the delta band. The proposed analytical tools allow for capturing the fine details of functional connectivity dynamics that are evidently present in DFC, with the presented results implying that multifractality is indeed an inherent property of both global and local DFC.

Early Detection of Hemodynamic Responses Using EEG: A Hybrid EEG-fNIRS Study.

Khan MJ, Ghafoor U, Hong KS.

Front Hum Neurosci. Nov 29;12:
doi: 10.3389/fnhum.2018.00479. eCollection 2018.

Enhanced classification accuracy and a sufficient number of commands are highly demanding in brain computer interfaces (BCIs). For a successful BCI, early detection of brain commands in time is essential. In this paper, we propose a novel classifier using a modified vector phase diagram and the power of electroencephalography (EEG) signal for early prediction of hemodynamic responses. EEG and functional near-infrared spectroscopy (fNIRS) signals for a motor task (thumb tapping) were obtained concurrently. Upon the resting state threshold circle in the vector phase diagram that uses the maximum values of oxy- and deoxy-hemoglobin (?HbO and ?HbR) during the resting state, we introduce a secondary (inner) threshold circle using the ?HbO and ?HbR magnitudes during the time window of 1 s where an EEG activity is noticeable. If the trajectory of ?HbO and ?HbR touches the resting state threshold circle after passing through the inner circle, this indicates that ?HbO was increasing and ?HbR was decreasing (i.e., the start of a hemodynamic response). It takes about 0.5 s for an fNIRS signal to cross the resting state threshold circle after crossing the EEG-based circle. Thus, an fNIRS-based BCI command can be generated in 1.5 s. We achieved an improved accuracy of 86.0% using the proposed method in comparison with the 63.8% accuracy obtained using linear discriminant analysis in a window of 0 1.5 s. Moreover, the active brain locations (identified using the proposed scheme) were spatially specific when a t-map was made after 10 s of stimulation. These results demonstrate the possibility of enhancing the classification accuracy for a brain-computer interface with a time window of 1.5 s using the proposed method.

Comparison of speed versus complexity effects on the hemodynamic response of the trail making test in block designs.

Rosenbaum D, Blum L, Schweizer P, Fallgatter AJ, Herrmann MJ, Ehlis AC, Metzger FG.

Neurophotonics. Oct;5(4):
doi: 10.1117/1.NPh.5.4.Epub 2018 Dec 8.

The use of functional near-infrared spectroscopy (fNIRS) in block designs provides measures of cortical activity in ecologically valid environ-

ments. However, in some cases, the use of block designs may be problematic when data are not corrected for performance in a time-restricted block. We sought to investigate the effects of task complexity and processing speed on hemodynamic responses in an fNIRS block design. To differentiate the effects of task complexity and processing speed, 20 subjects completed the trail making test (TMT) in two versions (TMT-A versus TMT-B) and three different speed levels (slow versus moderate versus fast). During TMT-A, subjects are asked to connect encircled numbers in numerically ascending order (1-2-3...). In the more complex TMT-B, subjects are instructed to connect encircled numbers and letters in alternating ascending order (1-A-2-B...). To illustrate the obscuring effects of processing speed on task complexity, we perform two different analyses. First, we analyze the classical measures of oxygenated blood, and second, we analyze the measures corrected for the number of processed items. Our results show large effects for processing speed within the bilateral inferior frontal gyrus, left dorsolateral prefrontal cortex, and superior parietal lobule (SPL). The TMT contrast did not show significant effects with classical measures, although trends are observed for higher activation during TMT-B. When corrected for processed items, higher activity for TMT-B in comparison to TMT-A is found within the SPL. The results are discussed in light of recent research designs, and simple to use correction methods are suggested.

An fNIRS-based investigation of visual merchandising displays for fashion stores.

Liu X, Kim CS, Hong KS.

PLoS One. Dec 11;13(12):e
doi: 10.1371/journal.pone.0208843. eCollection 2018.

This paper investigates a brain-based approach for visual merchandising display (VMD) in fashion stores. In marketing, VMD has become a research topic of interest. However, VMD research using brain activation information is rare. We examine the hemodynamic responses (HRs) in the prefrontal cortex (PFC) using functional near-infrared spectroscopy (fNIRS) while positive/negative displays of four stores (menswear, womenswear, underwear, and sportswear) are shown to 20 subjects. As features for classifying the HRs, the mean, variance, peak, skewness, kurtosis, t-value, and slope of the signals for a 20-sec time window for the activated channels are analyzed. Linear discriminant analysis is used for classifying two-class (positive and negative displays) and four-class (four fashion stores) models. PFC brain ac-

tivation maps based on t-values depicting the data from the 16 channels are provided. In the two-class classification, the underwear store had the highest average classification result of 67.04%, whereas the menswear store had the lowest value of 64.15%. Men's classification accuracy for the underwear stores with positive and negative displays was 71.38%, whereas the highest classification accuracy obtained by women for womenswear stores was 73%. The average accuracy over the 20 subjects for positive displays was 50.68%, while that of negative displays was 51.07%. Therefore, these findings suggest that human brain activation is involved in the evaluation of the fashion store displays. It is concluded that fNIRS can be used as a brain-based tool in the evaluation of fashion stores in a daily life environment.

Dynamic cortical connectivity alterations associated with Alzheimer's disease: An EEG and fNIRS integration study.

Li R, Nguyen T, Potter T, Zhang Y.

Neuroimage Clin. Dec pii: S2213-1582(18)30370-X.
doi: 10.1016/j.nicl.2018.[Epub ahead of print]

Emerging evidence indicates that cognitive deficits in Alzheimer's disease (AD) are associated with disruptions in brain network. Exploring alterations in the AD brain network is therefore of great importance for understanding and treating the disease. This study employs an integrative functional near-infrared spectroscopy (fNIRS) - electroencephalography (EEG) analysis approach to explore dynamic, regional alterations in the AD-linked brain network. FNIRS and EEG data were simultaneously recorded from 14 participants (8 healthy controls and 6 patients with mild AD) during a digit verbal span task (DVST). FNIRS-based spatial constraints were used as priors for EEG source localization. Graph-based indices were then calculated from the reconstructed EEG sources to assess regional differences between the groups. Results show that patients with mild AD revealed weaker and suppressed cortical connectivity in the high alpha band and in beta band to the orbitofrontal and parietal regions. AD-induced brain networks, compared to the networks of age-matched healthy controls, were mainly characterized by lower degree, clustering coefficient at the frontal pole and medial orbitofrontal across all frequency ranges. Additionally, the AD group also consistently showed higher index values for these graph-based indices at the superior temporal sulcus. These findings not only validate the feasibility of utilizing the proposed integrated EEG-fNIRS analysis to better understand the spatiotemporal dynamics of brain activity, but also contribute to the de-

velopment of network-based approaches for understanding the mechanisms that underlie the progression of AD.

Individual optimal attentional strategy during implicit motor learning boosts frontoparietal neural processing efficiency: A functional near-infrared spectroscopy study.

Sakurada T, Hirai M, Watanabe E.

Brain Behav. Jan;9(1):e
doi: 10.1002/brb3.Epub Dec 5.

INTRODUCTION: Optimal focus of attention is a crucial factor for improving motor learning. Most previous studies have shown that directing attention to movement outcome (external focus; EF) is more effective than directing attention to body movement itself (internal focus; IF). However, our recent studies demonstrated that the optimal attentional strategy in healthy and clinical populations varies depending on individual motor imagery ability. To explore the neurological basis underlying individual optimal attentional strategy during motor learning tasks, in the present study, we measured frontoparietal activities using functional near-infrared spectroscopy (fNIRS). METHODS: Twenty-eight participants performed a visuomotor learning task requiring circular tracking. During the task, the participants were required to direct their attention internally or externally. The individual optimal attentional strategy was determined by comparing the after-effect sizes between the IF and EF conditions. RESULTS: Fifteen participants showed larger after-effects under the EF condition (External-dominant), whereas the others showed larger after-effects under the IF condition (Internal-dominant). Based on the differences in neural activities between Internal- and External-dominant groups, we identified the right dorsolateral prefrontal cortex (Brodmann area 46) and right somatosensory association cortex (Brodmann area 7) as the neural bases associated with individual optimal attentional strategy during motor learning. Furthermore, we observed a significant negative correlation, that is, lower activity in these areas was associated with a larger after-effect size under the optimal attentional strategy. CONCLUSION: Our findings demonstrated that more efficient neural processing in the frontoparietal area under the individual optimal attentional strategy can accelerate motor learning.

Improvement in Recovery of Hemodynamic Responses by Extended Kalman Filter with Non-Linear State-Space Model and Short Separation Measurement.

Dong S, Jeong J.

IEEE Trans Biomed Eng. Nov
doi: 10.1109/TBME.2018.[Epub ahead of print]
DOI: 10.1109/TBME.2018.2884169 PMID: 30507523

Adaptive filtering of physiological noises in fNIRS data.

Nguyen HD, Yoo SH, Bhutta MR, Hong KS.

Biomed Eng Online. Dec 4;17(1):
doi: 10.1186/s12938-018-0613-2.

The study presents a recursive least-squares estimation method with an exponential forgetting factor for noise removal in functional near-infrared spectroscopy data and extraction of hemodynamic responses (HRs) from the measured data. The HR is modeled as a linear regression form in which the expected HR, the first and second derivatives of the expected HR, a short-separation measurement data, three physiological noises, and the baseline drift are included as components in the regression vector. The proposed method is applied to left-motor-cortex experiments on the right thumb and little finger movements in five healthy male participants. The algorithm is evaluated with respect to its performance improvement in terms of contrast-to-noise ratio in comparison with Kalman filter, low-pass filtering, and independent component method. The experimental results show that the proposed model achieves reductions of 77% and 99% in terms of the number of channels exhibiting higher contrast-to-noise ratios in oxyhemoglobin and deoxy-hemoglobin, respectively. The approach is robust in obtaining consistent HR data. The proposed method is applied for both offline and online noise removal.

Hemodynamic effects of sex and handedness on the Wisconsin Card Sorting Test: the contradiction between neuroimaging and behavioural results.

Cinciute S, Daktariunas A, Ruksenas O.

PeerJ. Nov 21;6:e
doi: 10.7717/peerj.eCollection 2018.

This study investigated the potential role of sex and handedness on the performance of a computerised Wisconsin Card Sorting Test (WCST) in healthy participants by applying functional near-infrared spectroscopy (fNIRS). We demonstrated significant ($p < 0.05$) sex-related differences of hemodynamic response in the prefrontal cortex of 70 healthy participants (female, n = 35 and male, n = 35; right-handed, n = 40 and left-handed, n = 30). In contrast, behavioural results of the WCST do not show sex bias, which is consistent with previous literature. Because of this, we compared ours and sparse previous fNIRS studies on the WCST. We propose that, according to recent studies of neurovascular coupling, this contradiction between neuroimaging and behavioural results may be explained by normal variability in neurovascular dynamics.

Functional Connectivity During Handgrip Motor Fatigue in Older Adults Is Obesity and Sex-Specific.

Rhee J, Mehta RK.

Front Hum Neurosci. Nov 13;12:
doi: 10.3389/fnhum.2018.00455. eCollection 2018.

The prevalence of obesity in older adults, particularly in females, is increasing rapidly and is associated with declines in both the brain and physical health. Both the obese and the female populations have shown greater motor fatigue than their counterparts, however, the central neural mechanisms for fatigue are unclear. The present study measured fatigue-related functional connectivity across frontal and sensorimotor areas using functional near-infrared spectroscopy (fNIRS). Fifty-nine older adults (30 non-obese and 29 obese) performed submaximal handgrip motor fatigue until voluntary exhaustion. Functional connectivity and cerebral hemodynamics were compared across eight cortical areas during motor fatigue and across obesity and sex groups along with neuromuscular fatigue outcomes (i.e., endurance time, strength loss, and force steadiness). Both obesity- and sex-specific functional architecture and mean activation differences during motor fatigue in older adults were observed, which were accompanied by fatigue-related changes in variability of force steadiness that differed between groups. While primary indicators of fatigue, i.e., endurance and strength loss, did not differ between groups, the motor steadiness changes indicated different neural adaptation strategies between the groups. These findings indicate that obesity and sex differences exist in brain function in older adults, which may affect performance during motor fatigue.

Early Detection of Alzheimer's Disease Using Non-invasive Near-Infrared Spectroscopy.

Li R, Rui G, Chen W, Li S, Schulz PE, Zhang Y.

Front Aging Neurosci. Nov 9;10:
doi: 10.3389/fnagi.2018.00366. eCollection 2018.

Mild cognitive impairment (MCI) is a cognitive disorder characterized by memory impairment, wherein patients have an increased likelihood of developing Alzheimer's disease (AD). The classification of MCI and different AD stages is therefore fundamental for understanding and treating the disease. This study aimed to comprehensively investigate the hemodynamic response patterns among various subject groups. Functional near-infrared spectroscopy (fNIRS) was employed to measure signals from the frontal and bilateral parietal cortices of healthy controls (n = 8), patients with MCI (n = 9), mild (n = 6), and moderate/severe AD (n = 7) during a digit verbal span task (DVST). The concentration changes of oxygenated hemoglobin (HbO) in various subject groups were thoroughly explored and tested. Result revealed that abnormal patterns of hemodynamic response were observed across all subject groups. Greater and steeper reductions in HbO concentration were consistently observed across all regions of interest (ROIs) as disease severity developed from MCI to moderate/severe AD. Furthermore, all the fNIRS-derived indexes were found to be significantly and positively correlated to the clinical scores in all ROIs ($R = 0.4$, $P < 0.05$). These findings demonstrate the feasibility of utilizing fNIRS for the early detection of AD, suggesting that fNIRS-based approaches hold great promise for exploring the mechanisms underlying the progression of AD.

Expectation affects neural repetition suppression in infancy.

Emberson LL, Boldin AM, Robertson CE, Cannon G, Aslin RN.

Dev Cogn Neurosci. Nov pii: S1878-9293(17)30107-X.
doi: 10.1016/j.dcn.2018.11.[Epub ahead of print]

Recent work provides evidence that the infant brain is able to make top-down predictions, but this has been explored only in limited contexts and domains. We build upon this evidence of predictive processing in infants using a new paradigm to examine auditory repetition suppression (RS). RS is a well-documented neural phenomenon in which repeated presentations of the same stimulus result in reduced neural activation compared to non-

repeating stimuli. Many theories explain RS using bottom-up mechanisms, but recent work has posited that top-down expectation and predictive coding may bias, or even explain, RS. Here, we investigate whether RS in the infant brain is similarly sensitive to top-down mechanisms. We use fNIRS to measure infants' neural response in two experimental conditions, one in which variability in stimulus presentation is expected (occurs 75% of the time) and a control condition where variability and repetition are equally likely (50% of the time). We show that 6-month-old infants exhibit attenuated frontal lobe response to blocks of variable auditory stimuli during contexts when variability is expected as compared to the control condition. These findings suggest that young infants' neural responses are modulated by predictions gained from experience and not simply by bottom-up mechanisms.

Monitoring multiple cortical regions during walking in young and older adults: Dual-task response and comparison challenges.

Stuart S, Alcock L, Rochester L, Vitorio R, Pantall A.

Int J Psychophysiol. Jan;135:63-
doi: 10.1016/j.ijpsycho.2018.11.006. Epub Nov 22.

Performance of several tasks simultaneously (dual-tasks) is common in everyday walking. Studies indicate that dual-task walking performance declines with age together with cognitive function, but neural mechanisms underpinning deficits remain unclear. Recent developments in mobile imaging techniques, such as functional near infrared spectroscopy (fNIRS), allow real-time monitoring of cortical activity during walking. This study aimed to: 1) examine activity in motor and cognitive cortical regions when walking with a dual-task in young and older adults; and 2) determine the effect of cognition on dual-task cortical activity changes. Seventeen young (20.3 1.2 years) and eighteen older adults (72.6 8.0 years) performed dual-task conditions, lasting 5 min, with alternating 30-second experimental blocks. The primary outcome was cortical activity, assessed by measuring changes in oxygenated haemoglobin (HbO2) concentrations. Cortical regions of interest (ROI) included motor regions (premotor cortex (PMC), supplementary motor area (SMA), primary motor cortex (M1)), and cognitive regions (prefrontal cortex (PFC)). Cognitive domains were assessed using standard tests and accelerometers were used to extract gait features. Cortical activity increased with a dual-task in PMC, SMA and M1 but not in PFC regions across groups, with response most evident with initial task expo-

sure. Older adults did not increase SMA activity with a dual-task to the same level as young adults. Dual-task cortical response was consistently associated with greater executive function across groups. In conclusion, both young and older adults responded in a similar manner to dual-task conditions. Dual-task walking activated multiple motor regions in both groups, but no significant change occurred for cognitive region activation. Cortical activation with a dual-task related to executive function.

Applications of Functional Near-Infrared Spectroscopy (fNIRS) Neuroimaging in Exercise?Cognition Science: A Systematic, Methodology-Focused Review.

Herold F, Wiegel P, Scholkmann F, Mller NG.

J Clin Med. Nov 22;7(12). pii: E
doi: 10.3390/jcm7120466.

For cognitive processes to function well, it is essential that the brain is optimally supplied with oxygen and blood. In recent years, evidence has emerged suggesting that cerebral oxygenation and hemodynamics can be modified with physical activity. To better understand the relationship between cerebral oxygenation/hemodynamics, physical activity, and cognition, the application of state-of-the art neuroimaging tools is essential. Functional near-infrared spectroscopy (fNIRS) is such a neuroimaging tool especially suitable to investigate the effects of physical activity/exercises on cerebral oxygenation and hemodynamics due to its capability to quantify changes in the concentration of oxygenated hemoglobin (oxyHb) and deoxygenated hemoglobin (deoxyHb) non-invasively in the human brain. However, currently there is no clear standardized procedure regarding the application, data processing, and data analysis of fNIRS, and there is a large heterogeneity regarding how fNIRS is applied in the field of exercise?cognition science. Therefore, this review aims to summarize the current methodological knowledge about fNIRS application in studies measuring the cortical hemodynamic responses during cognitive testing (i) prior and after different physical activities interventions, and (ii) in cross-sectional studies accounting for the physical fitness level of their participants. Based on the review of the methodology of 35 as relevant considered publications, we outline recommendations for future fNIRS studies in the field of exercise?cognition science.

Foot massage evokes oxytocin release and activation of orbitofrontal cortex and superior temporal sulcus.

Li Q, Becker B, Wernicke J, Chen Y, Zhang Y, Li R, Le J, Kou J, Zhao W, Kendrick KM.

Psychoneuroendocrinology. Nov 14;101:193-
doi: 10.1016/j.psyneuen.2018.11.[Epub ahead of print]

Massage may be an important method for increasing endogenous oxytocin concentrations and of potential therapeutic benefit in disorders with social dysfunction such as autism where basal oxytocin levels are typically reduced. Here we investigated oxytocin release and associated neural responses using functional near infrared spectroscopy (fNIRS) during hand- or machine-administered massage. 40 adult male subjects received 10?min of light foot massage either by hand or machine in a counterbalanced order and then rated pleasure, intensity, arousal and how much they would pay for the massage. Blood samples were taken before and after each massage condition to determine plasma oxytocin concentrations. Neural responses from medial and lateral orbitofrontal cortex, superior temporal sulcus and somatosensory cortex were measured (fNIRS oxy-Hb) together with skin conductance responses (SCR), ratings of the massage experience, autistic traits and sensitivity to social touch. Results showed subjects gave higher ratings of pleasure, but not intensity or arousal, after hand- compared with machine-administered massage and there were no differential effects on SCR. Subjects were also willing to pay more for the hand massage. Plasma oxytocin increased after both massage by hand or machine, but more potently after massage by hand. Both basal oxytocin concentrations and increases evoked by hand-, but not machine-administered massage, were negatively associated with trait autism and attitudes towards social touch, but massage by hand-evoked changes were significant in higher as well as lower trait individuals. Increased neural responses to hand vs. machine-administered massage were found in posterior superior temporal sulcus and medial/lateral orbitofrontal cortex but not somatosensory cortex. Orbitofrontal cortex and superior temporal cortex activation during hand massage was associated with the amount of money subjects were willing to pay and between orbitofrontal cortex activation and autism scores. Thus, hand-administered massage can potently increase oxytocin release and activity in brain regions involved in social cognition and reward but not sensory aspects of affective touch. Massage by hand induced changes in both oxytocin concentrations and neural circuits involved in processing social affective trust may have therapeutic potential in the context of autism.

Early Detection of Cerebral Infarction With Middle Cerebral Artery Occlusion With Functional Near-Infrared Spectroscopy: A Pilot Study.

Kwon H, Kim K, Jo YH, Park MJ, Ko SB, Kim TJ, Kang J, Bae HM, Lee JE.

Front Neurol. Nov 8;9:
doi: 10.3389/fneur.2018.eCollection 2018.

Background: NIRSIT, a functional near-infrared spectroscopy (fNIRS) device with 204 channels, can measure oxyhemoglobin (HbO2) and deoxyhemoglobin (HbR) in non-pulsatile blood flow non-invasively using the absorption difference between HbO2 and HbR at a wavelength of 700-1,000 nm and can display the perfusion status in real time. Objective: We applied NIRSIT to patients with stroke to evaluate the usefulness of NIRSIT as an fNIRS device for the early detection of stroke. Methods: We performed a prospective pilot study in an emergency department (ED). Adult patients who had suspected symptoms and signs of stroke within 12 h of the first abnormal time and who underwent intravenous thrombolysis (IVT) or intra-arterial thrombectomy with acute middle cerebral artery (MCA) or internal carotid artery (ICA) infarction were enrolled. NIRSIT was applied to the patients before the imaging study, and the perfusion status of the brain was displayed in real time at the bedside. We compared the NIRSIT results with the mean transit time (MTT) map from perfusion computed tomography (PCT) and the time-to-peak (TTP) map from perfusion-weighted magnetic resonance imaging (PWI). Results: Six male and three female patients were enrolled, and the median age was 74 years. The most common symptom was unilateral extremity weakness (77.8%), followed by dysarthria (33.3%) and aphasia (11.1%). The median National Institutes of Health Stroke Scale (NIHSS) score was 17. All cases of MCA infarction showed different cerebral oxygen saturation values between bilateral lobes of the brain in fNIRS imaging, and these values matched the PCT and PWI results. Conclusions: The brain hemisphere with low oxygen saturation on fNIRS showed hypoperfusion on PCT or PWI. The fNIRS device could be useful in assessing the perfusion status of the brain and detecting MCA or ICA infarction in real time at the bedside.

Directional changes in information flow between human brain

cortical regions after application of anodal transcranial direct current stimulation (tDCS) over Broca's area.

Cao J, Wang X, Liu H, Alexandrakis G.

Biomed Opt Express. Oct 10;9(11):5296-
doi: 10.1364/BOE.9.005296. eCollection Nov 1.

Little work has been done on the information flow in functional brain imaging and none so far in fNIRS. In this work, alterations in the directionality of net information flow induced by a short-duration, low-current (2 min 40 s; 0.5 mA) and a longer-duration, high-current (8 min; 1 mA) anodal tDCS applied over the Broca's area of the dominant language hemisphere were studied by fNIRS. The tDCS-induced patterns of information flow, quantified by a novel directed phase transfer entropy (dPTE) analysis, were distinct for different hemodynamic frequency bands and were qualitatively similar between low and high-current tDCS. In the endothelial band (0.003-0.02 Hz), the stimulated Broca's area became the strongest hub of outgoing information flow, whereas in the neurogenic band (0.02-0.04 Hz) the contralateral homologous area became the strongest information outflow source. In the myogenic band (0.04-0.15 Hz), only global patterns were seen, independent of tDCS stimulation that were interpreted as Mayer waves. These findings showcase dPTE analysis in fNIRS as a novel, complementary tool for studying cortical activity reorganization after an intervention.

Endurance Exercise Enhances Emotional Valence and Emotion Regulation.

Giles GE, Eddy MD, Bruny TT, Urry HL, Graber HL, Barbour RL, Mahoney CR, Taylor HA, Kanarek RB.

Front Hum Neurosci. Oct 16;12:
doi: 10.3389/fnhum.2018.00398. eCollection 2018.

Acute exercise consistently benefits both emotion and cognition, particularly cognitive control. We evaluated acute endurance exercise influences on emotion, domain-general cognitive control and the cognitive control of emotion, specifically cognitive reappraisal. Thirty-six endurance runners, defined as running at least 30 miles per week with one weekly run of at least 9 miles (21 female, age 18-30 years) participated. In a repeated measures design, participants walked at 57% age-adjusted maximum heart rate (HRmax; range 51%-63%) and ran at 70% HRmax (range 64%-76%) for 90 min on two separate days. Participants completed measures of emotional state and the Stroop test of domain-general cognitive control be-

fore, every 30 min during and 30 min after exercise. Participants also completed a cognitive reappraisal task (CRT) after exercise. Functional near-infrared spectroscopy (fNIRS) tracked changes in oxygenated and deoxygenated hemoglobin (O2Hb and dHb) levels in the prefrontal cortex (PFC). Results suggest that even at relatively moderate intensities, endurance athletes benefit emotionally from running both during and after exercise and task-related PFC oxygenation reductions do not appear to hinder prefrontal-dependent cognitive control.

Arithmetic learning modifies the functional connectivity of the fronto-parietal network.

Zhao H, Li X, Karolis V, Feng Y, Niu H, Butterworth B.

Cortex. Feb;111:51-

doi: 10.1016/j.cortex.2018.07.Epub Jul 31.

How Resting-State Functional Connectivity (RSFC) is modified by learning is an important but rarely asked question. Here we used functional near-infrared spectroscopy (fNIRS) to measure changes in RSFC after learning novel subtraction and multiplication facts by forty-one young adult volunteers. We also measured changes in regional hemoglobin concentration. Fronto-parietal RSFC was modified by arithmetic learning and the fronto-parietal RSFC configuration before learning predicted the effectiveness of arithmetic learning. We also found a significant learning effect indicated by a monotonic decrease in reaction time and an increase in accuracy. Regional task-dependent oxy-hemoglobin concentration differentiated subtraction from multiplication learning supporting previous fMRI findings. These results suggest the sensitivity and importance of fronto-parietal connectivity to arithmetic learning.

Acute Stress Attenuates Cognitive Flexibility in Males Only: An fNIRS Examination.

Kalia V, Vishwanath K, Knauft K, Vellen BV, Luebbe A, Williams A.

Front Psychol. Nov 1;9:

doi: 10.3389/fpsyg.2018.eCollection 2018.

Cognitive processes that afford us the ability to control thoughts and achieve goal-directed behavior are known as executive functions. Empirical evidence in the past few years has demonstrated that executive functions

can be influenced by acute stress. The impact of acute stress on cognitive flexibility, a key aspect of executive functions, has received little attention in the literature. We present the results of two experiments conducted to examine the effect of acute stress on cognitive flexibility. Acute stress was induced using the cold pressor task. Cognitive flexibility was assessed using the Wisconsin Card Sorting Test (WCST). Across both experiments acute stress had an attenuating effect on task switching on the WCST. Our findings also indicate that this effect was moderated by the participant's gender. In Study 1, we observed that following stress exposure male participants in the stress condition made more perseverative errors than participants in the control group. In Study 2, we examined the bilateral hemodynamics in the prefrontal cortex (PFC) during acute stress induction using functional near infrared spectroscopy (fNIRS). Our analysis indicated that functional oxyHb signals fluctuated with greater amplitude than systemic components for participants in the stress group relative to those in the control group. In addition, oxyHb levels post stress induction were correlated with performance on the WCST for the male participants in the stress group only. Concordant with previous reports, our findings indicate that acute stress impacts cognitive flexibility in males and females differentially. Our work also demonstrates the feasibility of using fNIRS as a practical and objective technique for the examination of hemodynamics in the PFC during acute stress.

The Application of Mobile fNIRS in Marketing Research-Detecting the "First-Choice-Brand" Effect.

Krampe C, Gier NR, Kenning P.

Front Hum Neurosci. Nov 1;12:

doi: 10.3389/fnhum.2018.eCollection 2018.

Recent research in the field of "neuro-marketing" shows promise to substantially increase knowledge on marketing issues for example price-perception, advertising efficiency, branding and shopper behaviour. Recently, an innovative and mobile applicable neuroimaging method has been proposed, namely functional near-infrared spectroscopy (fNIRS). However, this method is, in the research field of marketing, still in its infancy and is, consequently, lacking substantial validity. Against this background, this research work applied a convergent validity approach to challenge the validity of (mobile) fNIRS in the field of "neuro-marketing" and consumer neuroscience. More precisely, we aim to replicate a robust and well-investigated neural effect

previously detected with fMRI-namely the "first-choice-brand" effect-by using mobile fNIRS. The research findings show that mobile fNIRS appears to be an appropriate neuroimaging method for research in the field of "neuromarketing" and consumer neuroscience. Additionally, this research work presents guidelines, enabling marketing scholars to utilise mobile fNIRS in their research work.

Within- and Between-Session Prefrontal Cortex Response to Virtual Reality Exposure Therapy for Acrophobia.

Landowska A, Roberts D, Eachus P, Barrett A.

Front Hum Neurosci. Nov 1;12:

doi: 10.3389/fnhum.2018.eCollection 2018.

Exposure Therapy (ET) has demonstrated its efficacy in the treatment of phobias, anxiety and Post-traumatic Stress Disorder (PTSD), however, it suffers a high drop-out rate because of too low or too high patient engagement in treatment. Virtual Reality Exposure Therapy (VRET) is comparably effective regarding symptom reduction and offers an alternative tool to facilitate engagement for avoidant participants. Neuroimaging studies have demonstrated that both ET and VRET normalize brain activity within a fear circuit. However, previous studies have employed brain imaging technology which restricts people's movement and hides their body, surroundings and therapist from view. This is at odds with the way engagement is typically controlled. We used a novel combination of neural imaging and VR technology-Functional Near-Infrared Spectroscopy (fNIRS) and Immersive Projection Technology (IPT), to avoid these limitations. Although there are a few studies that have investigated the effect of VRET on a brain function after the treatment, the present study utilized technologies which promote ecological validity to measure brain changes after VRET treatment. Furthermore, there are no studies that have measured brain activity within VRET session. In this study brain activity within the prefrontal cortex (PFC) was measured during three consecutive exposure sessions. N = 13 acrophobic volunteers were asked to walk on a virtual plank with a 6 m drop below. Changes in oxygenated (HbO) hemoglobin concentrations in the PFC were measured in three blocks using fNIRS. Consistent with previous functional magnetic resonance imaging (fMRI) studies, the analysis showed decreased activity in the DLPFC and MPFC during first exposure. The activity increased toward normal across three sessions. The study demonstrates potential efficacy of a method for measuring within-session neural response to

virtual stimuli that could be replicated within clinics and research institutes, with equipment better suited to an ET session and at fraction of the cost, when compared to fMRI. This has application in widening access to, and increasing ecological validity of, immersive neuroimaging across understanding, diagnosis, assessment and treatment of, a range of mental disorders such as phobia, anxiety and PTSD or addictions.

A Modified Common Spatial Pattern Algorithm Customized for Feature Dimensionality Reduction in fNIRS-Based BCIs.
Jiang X, Gu X, Mei Z, Ren H, Chen W.
Conf Proc IEEE Eng Med Biol Soc. Jul;2018:5073-
doi: 10.1109/EMBC.2018.8513454.
DOI: 10.1109/EMBC.2018.8513454 PMID: 30441481

Supra-Spinal Modulation Of Walking In Healthy Individuals And Persons With Multiple Sclerosis: A fNIRS Mobile Imaging Study.
Saleh S, Sandroff BM, Owoeye O, Vitiello T, Hoxha A, Yue G, DeLuca J.
Conf Proc IEEE Eng Med Biol Soc. Jul;2018:3156-
doi: 10.1109/EMBC.2018.8513052.
DOI: 10.1109/EMBC.2018.8513052 PMID: 30441064

Near-Infrared Spectroscopy studies on TBI patients with Modified Multiscale Entropy analysis.
Wang H, Ren H, Jiang X, Sun Y, Wang Z, Chen W.
Conf Proc IEEE Eng Med Biol Soc. Jul;2018:2853-
doi: 10.1109/EMBC.2018.8512885.
DOI: 10.1109/EMBC.2018.8512885 PMID: 30440996

Enhancement of cortical activation for motor imagery during BCI-FES training.
Wang Z, Chen L, Yi W, Gu B, Liu S, An X, Xu M, Qi H, He F, Wan B, Ming D.

Conf Proc IEEE Eng Med Biol Soc. Jul;2018:2527-
doi: 10.1109/EMBC.2018.8512749.
DOI: 10.1109/EMBC.2018.8512749 PMID: 30440922

Functional near infrared spectroscopy in the noninvasive assessment of brain death.

Li T, Pan B.

Conf Proc IEEE Eng Med Biol Soc. Jul;2018:1538-
doi: 10.1109/EMBC.2018.8512489.
DOI: 10.1109/EMBC.2018.8512489 PMID: 30440686

Optimizing Mental Workload by Functional Near-Infrared Spectroscopy Based Dynamic Difficulty Adjustment.

Ung WC, Meriaudeau F, Tang TB.

Conf Proc IEEE Eng Med Biol Soc. Jul;2018:1522-
doi: 10.1109/EMBC.2018.8512501.
DOI: 10.1109/EMBC.2018.8512501 PMID: 30440682

Brain-to-brain synchronization of the expectation of cooperation behavior: A fNIRS hyperscanning study.

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

Conf Proc IEEE Eng Med Biol Soc. Jul;2018:546-
doi: 10.1109/EMBC.2018.8512315.
DOI: 10.1109/EMBC.2018.8512315 PMID: 30440455

Classifying the mental representation of word meaning in children with Multivariate Pattern Analysis of fNIRS.

Gemignani J, Bayet L, Kabdebon C, Blankertz B, Pugh KR, Aslin RN.

Conf Proc IEEE Eng Med Biol Soc. Jul;2018:295-
doi: 10.1109/EMBC.2018.8512209.
DOI: 10.1109/EMBC.2018.8512209 PMID: 30440396

Functional Connectivity Analysis on Mild Alzheimer's Disease, Mild Cognitive Impairment and Normal Aging using fNIRS.

Tang TB, Chan YL.

Conf Proc IEEE Eng Med Biol Soc. Jul;2018:17-
doi: 10.1109/EMBC.2018.8512186.

DOI: 10.1109/EMBC.2018.8512186 PMID: 30440330

Editorial: Detection and Estimation of Working Memory States and Cognitive Functions Based on Neurophysiological Measures.

Putze F, Mhl C, Lotte F, Fairclough S, Herff C.

Front Hum Neurosci. Oct 30;12:
doi: 10.3389/fnhum.2018.00440. eCollection 2018.

DOI: 10.3389/fnhum.2018.00440 PMCID: PMC6218507 PMID: 30425630

High Oxygen Exchange to Music Indicates Auditory Distractibility in Acquired Brain Injury: An fNIRS Study with a Vector-Based Phase Analysis.

Jeong E, Ryu H, Shin JH, Kwon GH, Jo G, Lee JY.

Sci Rep. Nov 13;8(1):
doi: 10.1038/s41598-018-35172-2.

Attention deficits due to auditory distractibility are pervasive among patients with acquired brain injury (ABI). It remains unclear, however, whether attention deficits following ABI specific to auditory modality are associated with altered haemodynamic responses. Here, we examined cerebral haemodynamic changes using functional near-infrared spectroscopy combined with a topological vector-based analysis method. A total of thirty-seven participants (22 healthy adults, 15 patients with ABI) performed a melodic contour identification task (CIT) that simulates auditory distractibility. Findings demonstrated that the melodic CIT was able to detect auditory distractibility in patients with ABI. The rate-corrected score showed that the ABI group performed significantly worse than the non-ABI group in both CIT1 (target contour identification against environmental sounds) and CIT2 (target contour identification against target-like distraction). Phase-associated response intensity during the CITs was greater in

the ABI group than in the non-ABI group. Moreover, there existed a significant interaction effect in the left dorsolateral prefrontal cortex (DLPFC) during CIT1 and CIT2. These findings indicated that stronger hemodynamic responses involving oxygen exchange in the left DLPFC can serve as a biomarker for evaluating and monitoring auditory distractibility, which could potentially lead to the discovery of the underlying mechanism that causes auditory attention deficits in patients with ABI.

Pilot Study on Gait Classification Using fNIRS Signals.
Jin H, Li C, Xu J.
Comput Intell Neurosci. Oct 17;2018:
doi: 10.1155/2018/7403471. eCollection 2018.

Rehabilitation training is essential for motor dysfunction patients, and the training through their subjective motion intention, comparing to passive training, is more conducive to rehabilitation. This study proposes a method to identify motion intention of different walking states under the normal environment, by using the functional near-infrared spectroscopy (fNIRS) technology. Twenty-two healthy subjects were recruited to walk with three different gaits (including small-step with low-speed, small-step with mid-speed, midstep with low-speed). The wavelet packet decomposition was used to find out the main characteristic channels in different motion states, and these channels with links in frequency and space were combined to define as feature vectors. According to different permutations and combinations of all feature vectors, a library for support vector machines (libSVM) was used to achieve the best recognition model. Finally, the accuracy rate of these three walking states was 78.79%. This study implemented the classification of different states' motion intention by using the fNIRS technology. It laid a foundation to apply the classified motion intention of different states timely, to help severe motor dysfunction patients control a walking-assistive device for rehabilitation training, so as to help them restore independent walking abilities and reduce the economic burdens on society.

Existence of Initial Dip for BCI: An Illusion or Reality.
Hong KS, Zafar A.
Front Neurorobot. Oct 26;12:
doi: 10.3389/fnbot.2018.eCollection 2018.

A tight coupling between the neuronal activity and the cerebral blood flow (CBF) is the motivation of many hemodynamic response (HR)-based neuroimaging modalities. The increase in neuronal activity causes the increase in CBF that is indirectly measured by HR modalities. Upon functional stimulation, the HR is mainly categorized in three durations: (i) initial dip, (ii) conventional HR (i.e., positive increase in HR caused by an increase in the CBF), and (iii) undershoot. The initial dip is a change in oxygenation prior to any subsequent increase in CBF and spatially more specific to the site of neuronal activity. Despite additional evidence from various HR modalities on the presence of initial dip in human and animal species (i.e., cat, rat, and monkey); the existence/occurrence of an initial dip in HR is still under debate. This article reviews the existence and elusive nature of the initial dip duration of HR in intrinsic signal optical imaging (ISOI), functional magnetic resonance imaging (fMRI), and functional near-infrared spectroscopy (fNIRS). The advent of initial dip and its elusiveness factors in ISOI and fMRI studies are briefly discussed. Furthermore, the detection of initial dip and its role in brain-computer interface using fNIRS is examined in detail. The best possible application for the initial dip utilization and its future implications using fNIRS are provided.

Reduced Gait Variability and Enhanced Brain Activity in Older Adults With Auditory Cues: A Functional Near-Infrared Spectroscopy Study.

Vitorio R, Stuart S, Gobbi LTB, Rochester L, Alcock L, Pantall A.

Neurorehabil Neural Repair. Nov;32(11):976-
doi: 10.1177/1545968318805159.

BACKGROUND: Aging is associated with declining mobility, which negatively affects quality of life and incurs substantial economic costs. Techniques to maintain safe mobility in older adults are therefore essential. Rhythmic auditory cueing (RAC) can improve walking patterns in older adults. However, the neural correlates associated with RAC, how they are influenced by repeated exposure and their relationships with gait response, cognitive function, and depressive symptoms are unclear. OBJECTIVES: This study aimed to investigate the effects of RAC during walking on cortical activation and the relationship between RAC-related cortical changes and cognitive function, depressive symptoms, and gait response. METHODS: Seventeen young adults and eighteen older adults walked on a motorized treadmill for 5 minutes (5 trials with alternating 30-second blocks

of usual walking and RAC walking). Changes in oxygenated hemoglobin (HbO2) in the frontal cortex were recorded using functional near-infrared spectroscopy. Cognitive domains were assessed through validated tests. A triaxial accelerometer measured gait parameters. RESULTS: Gait variability decreased and prefrontal HbO2 levels increased during cued walking relative to usual walking. Older adults showed greater HbO2 levels in multiple motor regions during cued walking although the response reduced with repeated exposure. In older adults, lower depression scores, higher cognitive functioning, and reduced gait variability were linked with increased HbO2 levels during RAC walking. CONCLUSION: These findings suggest that walking improves with RAC in older adults and is achieved through increased activity in multiple cortical areas. The cortical response decline with repeated exposure indicates older adults' ability to adapt to a new task.

The effect of polypharmacy on prefrontal cortex activation during single and dual task walking in community dwelling older adults.

George CJ, Verghese J, Izzetoglu M, Wang C, Holtzer R.

Pharmacol Res. Jan;139:113-

doi: 10.1016/j.phrs.2018.11.Epub 2018 Nov 5.

INTRODUCTION: Polypharmacy, defined as the use of 5 or more medications is associated with multiple adverse outcomes in older adults, including falls and slow gait velocity. However, the relationship between polypharmacy and cortical control of locomotion has not been reported. The purpose of this study was to examine the relationship between polypharmacy and activation patterns in the prefrontal cortex (PFC), a brain region involved in higher order control of locomotion during attention-demanding conditions. METHODS: Using Functional Near Infrared Spectroscopy (fNIRS) to quantify PFC oxygenated hemoglobin (HbO2) levels, we performed a cross sectional analysis of 325 community dwelling adults age =65 years, and examined HbO2 levels during single tasks (Single-Task-Walk (STW), (talking, cognitive interference (Alpha)) and Dual-Task Walk (DTW)). RESULTS: The prevalence of polypharmacy was 33% (n?=?104) amongst the 325 participants (mean age 76.4??6.7 years, 56% women). Among the 221 participants with no polypharmacy there was an increase in HbO2 levels from STW to DTW (estimate?=?-0.625; p?=?<0.001) and from Alpha to DTW (estimate=-0.079; p?=?0.031). Polypharmacy status, however, mod-

erated the change in HbO2 levels comparing the two single tasks to the dual-task walking condition. Specifically, the presence of polypharmacy was associated with an attenuated increase in HbO2 levels from STW to DTW (estimate?=?0.149; p?=?0.027) and with a decline in HbO2 levels from Alpha to DTW (estimate?=?0.169; p?=?0.009) after adjustments for potential confounders including medical comorbidities and the use of high-risk medications. CONCLUSION: The results of this study further support the need for clinicians to reduce polypharmacy in older adults, given its significant association with the PFC hemodynamic response during attention-demanding locomotion.

Neuroticism is associated with reduced oxygenation levels in the lateral prefrontal cortex following exposure to unpleasant images.

Balada F, Lucas I, Blanch , Blanco E, Aluja A.

Physiol Behav. Feb 1;199:66-

doi: 10.1016/j.physbeh.2018.11.Epub Nov 5.

The aim of this study was to explore the prefrontal cortex response to emotional salient stimuli in subjects with high scores in Neuroticism (and low in Sensation Seeking) or high scores in Sensation Seeking (and low in Neuroticism) personality traits, -called now Neuroticism and Sensation Seeking groups-. For this purpose, we selected 24 females (mean age: 20; SD: 1.74 years) and assigned them to two different groups according to their extreme score in personality dimensions. Ten pleasant and ten unpleasant pictures from the International Affective Picture System were presented. Neuroticism group showed significant effects for valence at the lateral prefrontal cortex in both brain hemispheres. They showed higher Oxygenation for pleasant pictures, more significantly in the left ($Z = 2.49$, $p = 0.01$) than in the right hemisphere ($Z = 2.19$, $p = 0.03$). The highest differences were registered in ventral optodes. In contrast, Sensation Seeking group did not show significant differences in hemodynamic variables as depending on the valence of the pictures. These data suggest a differential functioning of the lateral prefrontal cortex, mainly the left ventrolateral cortex, in Neuroticism group to pleasant and unpleasant visual stimuli. We hypothesize that if the lateral prefrontal activity is low, it could be the result of an over-activation of the amygdala in response to unpleasant pictures in subjects with Neuroticism or negative emotionality. These activation patterns could be related to vulnerability to emotional disorders.

Stress assessment by means of heart rate derived from functional near-infrared spectroscopy.

Hakimi N, Setarehdan SK.

J Biomed Opt. Nov;23(11):1-
doi: 10.1117/1.JBO.23.11.115001.

Many studies have been carried out in order to detect and quantify the level of mental stress by means of different physiological signals. From the physiological point of view, stress promptly affects brain and cardiac function; therefore, stress can be assessed by analyzing the brain- and heart-related signals more efficiently. Signals produced by functional near-infrared spectroscopy (fNIRS) of the brain together with the heart rate (HR) are employed to assess the stress induced by the Montreal Imaging Stress Task. Two different versions of the HR are used in this study. The first one is the commonly used HR derived from the electrocardiogram (ECG) and is considered as the reference HR (RHR). The other is the HR computed from the fNIRS signal (EHR) by means of an effective combinational algorithm. fNIRS and ECG signals were simultaneously recorded from 10 volunteers, and EHR and RHR are derived from them, respectively. Our results showed a high degree of agreement [r??>??0.9, BAR (Bland Altman ratio) <5??%??] between the two HR. A principal component analysis/support vector machine-based algorithm for stress classification is developed and applied to the three measurements of fNIRS, EHR, and RHR and a classification accuracy of 78.8%, 94.6%, and 62.2% were obtained for the three measurements, respectively. From these observations, it can be concluded that the EHR carries more useful information with regards to the mental stress than the RHR and fNIRS signals. Therefore, EHR can be used alone or in combination with the fNIRS signal for a more accurate and real-time stress detection and classification.

Modality-independent recruitment of inferior frontal cortex during speech processing in human infants.

Altvater-Mackensen N, Grossmann T.

Dev Cogn Neurosci. Nov;34:130-
doi: 10.1016/j.dcn.2018.10.Epub 2018 Oct 30.

Despite increasing interest in the development of audiovisual speech perception in infancy, the underlying mechanisms and neural processes are still

only poorly understood. In addition to regions in temporal cortex associated with speech processing and multimodal integration, such as superior temporal sulcus, left inferior frontal cortex (IFC) has been suggested to be critically involved in mapping information from different modalities during speech perception. To further illuminate the role of IFC during infant language learning and speech perception, the current study examined the processing of auditory, visual and audiovisual speech in 6-month-old infants using functional near-infrared spectroscopy (fNIRS). Our results revealed that infants recruit speech-sensitive regions in frontal cortex including IFC regardless of whether they processed unimodal or multimodal speech. We argue that IFC may play an important role in associating multimodal speech information during the early steps of language learning.

Studying brain activity in sports performance: Contributions and issues.

Perrey S, Besson P.

Prog Brain Res. 2018;240:247-
doi: 10.1016/bs.pbr.2018.07.Epub Aug 27.

Understanding the interactions between brain activity and behavior comprehensively in achieving optimal exercise performance in sports is still lacking. The existent research in this area has been limited by the constraints of sports environments and the robustness of the most suitable non-invasive functional neuroimaging methods (electroencephalography, EEG and functional near-infrared spectroscopy, fNIRS) to motion artifacts and noise. However, recent advances in brain mapping technology should improve the capabilities of the future brain imaging devices to assess and monitor the level of adaptive cognitive-motor performance during exercise in sports environments. The purpose of this position manuscript is to discuss the contributions and issues in behavioral neuroscience related to brain activity measured during exercise and in various sports. A first part aims to give an overview of EEG and fNIRS neuroimaging methods assessing electrophysiological activity and hemodynamic responses of the acute and chronic relation of physical exercise on the human brain. Then, methodological issues, such as the reliability of brain data during physical exertion, key limitations and possible prospects of fNIRS and EEG methods are provided. While the use of such methods in sports environments remains scarce and limited to controlled cycling task, new generation of wearable, whole-scalp EEG and fNIRS technologies could open up a range of new applications in sports sci-

ences for providing neuroimaging-based biomarkers (hemodynamic and/or neural electrical signals) to various types of exercise and innovative training.

Brain mechanisms that underlie music interventions in the exercise domain.

Karageorghis CI, Bigliassi M, Gurin SMR, Delevoye-Turrell Y.

Prog Brain Res. 2018;240:109-
doi: 10.1016/bs.pbr.2018.09.Epub Oct 24.

In this chapter we review recent work from the realms of neuroscience and neuropsychology to explore the brain mechanisms that underlie the effects of music on exercise. We begin with an examination of the technique of electroencephalography (EEG), which has proven popular with researchers in this domain. We go on to appraise work conducted with the use of functional magnetic resonance imaging (fMRI) and then, looking more toward the future, we consider the application of functional near-infrared spectroscopy (fNIRS) to study brain hemodynamics. The experimental findings expounded herein indicate that music has the potential to guide attention toward environmental sensory cues and prevent internal, fatigue-related signals from entering focal awareness. The brain mechanisms underlying such effects are primarily associated with the downregulation of theta waves across the cortex surface, reduction of communication among somatosensory regions, and increased activation of the left inferior frontal gyrus. Taken holistically, research in this subfield of exercise psychology demonstrates a vibrant and reflexive matrix of attentional, emotional, behavioral, physiological, and psychophysiological responses to music across a variety of exercise modalities and intensities. The emergent hypotheses that we propose can be used to frame future research efforts.

Exploring brain functional connectivity in rest and sleep states: a fNIRS study.

Nguyen T, Babawale O, Kim T, Jo HJ, Liu H, Kim JG.

Sci Rep. Nov 1;8(1):
doi: 10.1038/s41598-018-33439-2.

This study investigates the brain functional connectivity in the rest and sleep states. We collected EEG, EOG, and fNIRS signals simultaneously during rest and sleep phases. The rest phase was defined as a quiet wake-

eyes open (w_o) state, while the sleep phase was separated into three states; quiet wake-eyes closed (w_c), non-rapid eye movement sleep stage 1 (N1), and non-rapid eye movement sleep stage 2 (N2) using the EEG and EOG signals. The fNIRS signals were used to calculate the cerebral hemodynamic responses (oxy-, deoxy-, and total hemoglobin). We grouped 133 fNIRS channels into five brain regions (frontal, motor, temporal, somatosensory, and visual areas). These five regions were then used to form fifteen brain networks. A network connectivity was computed by calculating the Pearson correlation coefficients of the hemodynamic responses between fNIRS channels belonging to the network. The fifteen networks were compared across the states using the connection ratio and connection strength calculated from the normalized correlation coefficients. Across all fifteen networks and three hemoglobin types, the connection ratio was high in the w_c and N1 states and low in the w_o and N2 states. In addition, the connection strength was similar between the w_c and N1 states and lower in the w_o and N2 states. Based on our experimental results, we believe that fNIRS has a high potential to be a main tool to study the brain connectivity in the rest and sleep states.

Activity of frontal pole cortex reflecting hedonic tone of food and drink: fNIRS study in humans.

Minematsu Y, Ueji K, Yamamoto T.

Sci Rep. Nov 1;8(1):
doi: 10.1038/s41598-018-34690-3.

Cognitive and hedonic aspects of taste have been studied using different neuroimaging techniques in humans. However, the methods used are unsuitable for easy monitoring of hedonics induced by intake of foods and beverages. Here we have tried to monitor changes in oxygenated hemoglobin (oxyHb) levels in the anterior prefrontal cortex (aPFC, frontopolar cortex, Brodmann area 10) in response to intake of hedonically different edibles in healthy adults. When subjects tasted sweet and bitter solutions freely without any particular instruction, cortical activation varied greatly among subjects and between the two stimuli, and no consistent results were obtained. Subjects then ate or drank preferred (hedonically positive) and disliked (hedonically negative) edibles. Although these stimuli differed among subjects, hedonically positive stimuli decreased oxyHb, whereas hedonically negative stimuli increased oxyHb, particularly in the ventral aPFC. When subjects tasted 4 kinds of jellies with different flavors and evaluated the de-

gree of pleasantness, oxyHb level in the ventral region correlated negatively with pleasantness score. These results revealed that pleasant and unpleasant edibles tended to elicit decreased and increased oxyHb levels, respectively, within the ventral aPFC, suggesting that monitoring of oxyHb in this region may prove useful for objective evaluation of pleasantness of food and drink.

Prefrontal cortex response to drug cues, craving, and current depressive symptoms are associated with treatment outcomes in methadone-maintained patients.

Huhn AS, Sweeney MM, Brooner RK, Kidorf MS, Tompkins DA, Ayaz H, Dunn KE.

Neuropsychopharmacology. Oct
doi: 10.1038/s41386-018-0252-[Epub ahead of print]

Methadone maintenance is an effective treatment for opioid use disorder, yet many methadone-maintained patients (MMPs) continue to struggle with chronic relapse. The current study evaluated whether functional near-infrared spectroscopy (fNIRS) could identify prefrontal cortex (PFC) markers of ongoing opioid use in MMPs, and whether clinical measures of depression and self-report measures of craving would also be associated with opioid use. MMPs (n?=?29) underwent a drug cue reactivity paradigm during fNIRS measurements of PFC reactivity. Self-reported opioid craving (measured by a visual analog scale; 0-100) was collected before and after drug cue reactivity, and depressive symptoms were assessed via the 17-item Hamilton Depression Rating Scale (HAM-D). Hierarchical regression and partial correlations were used to evaluate associations between weekly urine drug screens over a 90-day follow-up period and fNIRS, craving, and HAM-D assessments. Neural response to drug cues in the left lateral PFC, controlling for age, sex, and days in treatment was significantly associated with percent opioid-negative urine screens during follow-up (?F1,?24?=?13.19, p?=?0.001, ?R2?=?0.30), and correctly classified 86% of MMPs as either using opioids, or abstaining from opioids (?2(4)?=?16.28, p?=?0.003). Baseline craving (p?<?0.001) and HAM-D assessment (p?<?0.01) were also associated with percent opioid-negative urine screens. Combining fNIRS results, baseline craving scores, and HAM-D scores created a robust predictive model (?F3,?22?=?16.75, p?<?0.001, ?R2?=?0.59). These data provide preliminary evidence that the fNIRS technology may have value as an objective measure of treatment outcomes within outpatient methadone clinics. Depressive symptoms and drug craving were also correlated with opioid use in

MMPs.

Brain activity in response to the touch of a hand on the center of the back.

Morita I, Sakuma S, Shimomura J, Hayashi N, Toda S.

PLoS One. Oct 29;13(10):e
doi: 10.1371/journal.pone.0206451. eCollection 2018.

The aim of this study was to validate the possibility of using functional Near-Infrared Spectroscopy (fNIRS) to measure changes in cerebral blood flow in response to a hand being placed on a participant's back, and to identify the areas of enhanced activity in the brain. Nineteen female adult volunteers participated in the study. An experienced school nurse touched the center of the participant's back between the shoulder blades with the palm of her hand. Cerebral blood volume dynamics were measured with a 52-channel fNIRS system. Significantly higher oxygenated hemoglobin (oxy-Hb) concentration levels were recorded by channels 11, 14, 21, 22, 24, 32, 35, 45, 46, and 49 during the touching period than during the resting period. These channels indicated enhanced activity in the supramarginal gyrus, the middle frontal gyrus, the superior temporal gyrus, and the inferior frontal gyrus. The ability to detect changes in cerebral blood flow using this method indicates the possibility of measuring changes in cerebral blood flow using fNIRS when a person is touched on the back. fNIRS has been shown to be useful for studying the effects of touch.

Stride-time variability is related to sensorimotor cortical activation during forward and backward walking.

Groff BR, Antonellis P, Schmid KK, Knarr BA, Stergiou N.

Neurosci Lett. Jan 23;692:150-
doi: 10.1016/j.neulet.2018.10.Epub Oct 24.

Previous research has used functional near-infrared spectroscopy (fNIRS) to show that motor areas of the cortex are activated more while walking backward compared to walking forward. It is also known that head movement creates motion artifacts in fNIRS data. The aim of this study was to investigate cortical activation during forward and backward walking, while also measuring head movement. We hypothesized that greater activation in motor areas while walking backward would be concurrent with increased

head movement. Participants performed forward and backward walking on a treadmill. Participants wore motion capture markers on their head to quantify head movement and pressure sensors on their feet to calculate stride-time. fNIRS was placed over motor areas of the cortex to measure cortical activation. Measurements were compared for forward and backward walking conditions. No significant differences in body movement or head movement were observed between forward and backward walking conditions, suggesting that conditional differences in movement did not influence fNIRS results. Stride-time was significantly shorter during backward walking than during forward walking, but not more variable. There were no differences in activation for motor areas of the cortex when outliers were removed. However, there was a positive correlation between stride-time variability and activation in the primary motor cortex. This positive correlation between motor cortex activation and stride-time variability suggests that forward walking variability may be represented in the primary motor cortex.

From the Laboratory to the Classroom: The Potential of Functional Near-Infrared Spectroscopy in Educational Neuroscience.

Brockington G, Balardin JB, Zimeo Morais GA, Malheiros A, Lent R, Moura LM, Sato JR.

Front Psychol. Oct 11;9:
doi: 10.3389/fpsyg.2018.eCollection 2018.

Paralleling two decades of growth in the emergent field known as educational neuroscience is an increasing concern that educational practices and programs should be evidence-based, however, the idea that neuroscience could potentially influence education is controversial. One of the criticisms, regarding applications of the findings produced in this discipline, concerns the artificiality of neuroscientific experiments and the oversimplified nature of the tests used to investigate cognitive processes in educational contexts. The simulations may not account for all of the variables present in real classroom activities. In this study, we aim to get a step closer to the formation of data-supported classroom methodologies by employing functional near-infrared spectroscopy in various experimental paradigms. First, we present two hyperscanning scenarios designed to explore realistic interdisciplinary contexts, i.e., the classroom. In a third paradigm, we present a case study of a single student evaluated with functional near-infrared spectroscopy and mobile eye-tracking glasses. These three experiments are performed to pro-

vide proofs of concept for the application of functional near-infrared spectroscopy in scenarios that more closely resemble authentic classroom routines and daily activities. The goal of our study is to explore the potential of this technique in hopes that it offers insights in experimental design to investigate teaching-learning processes during teacher-student interactions.

Increase in prefrontal cortex oxygenation during static muscular endurance performance is modulated by self-regulation strategies.

Wolff W, Bieleke M, Hirsch A, Wienbruch C, Gollwitzer PM, Schler J.

Sci Rep. Oct 25;8(1):
doi: 10.1038/s41598-018-34009-2.

Enduring physical strain is an important ability and prototypically required in athletic activities. However, little is known about the psychological determinants of endurance performance and their underlying neural mechanisms. Here, we investigated self-regulation as one such factor. We recruited 60 participants who hold intertwined rings for as long as possible while avoiding contacts between them, either with a goal intention or an implementation intention to perform well. Performance was measured in terms of time-to-failure and contact errors. Additionally, we repeatedly assessed ratings of perceived exertion (RPE) and pain (RPP) and used functional near-infrared spectroscopy (fNIRS) to continuously monitor cerebral oxygenation in dorsal and ventral parts of the lateral prefrontal cortex (LPFC), brain regions associated with effortful attentional control and response inhibition, respectively. Performance, RPE and RPP were similar in the goal and the implementation intention condition. LPFC activity increased over time, but its activation level was generally lower in the implementation intention condition. Both effects were particularly pronounced in the dorsal LPFC. Moreover, the balance between effortful and more automatic regulation seems to differ between self-regulation strategies. Our results indicate that self-regulation plays an important role in endurance performance and that self-regulatory processes during endurance performance might be reflected in LPFC activation.

Speech Recognition via fNIRS Based Brain Signals.

Liu Y, Ayaz H.

Front Neurosci. Oct 9;12:
doi: 10.3389/fnins.2018.eCollection 2018.

In this paper, we present the first evidence that perceived speech can be identified from the listeners' brain signals measured via functional-near infrared spectroscopy (fNIRS)-a non-invasive, portable, and wearable neuroimaging technique suitable for ecologically valid settings. In this study, participants listened audio clips containing English stories while prefrontal and parietal cortices were monitored with fNIRS. Machine learning was applied to train predictive models using fNIRS data from a subject pool to predict which part of a story was listened by a new subject not in the pool based on the brain's hemodynamic response as measured by fNIRS. fNIRS signals can vary considerably from subject to subject due to the different head size, head shape, and spatial locations of brain functional regions. To overcome this difficulty, a generalized canonical correlation analysis (GCCA) was adopted to extract latent variables that are shared among the listeners before applying principal component analysis (PCA) for dimension reduction and applying logistic regression for classification. A 74.7% average accuracy has been achieved for differentiating between two 50 s. long story segments and a 43.6% average accuracy has been achieved for differentiating four 25 s. long story segments. These results suggest the potential of an fNIRS based-approach for building a speech decoding brain-computer-interface for developing a new type of neural prosthetic system.

Emotion Regulation in Schizophrenia: A Pilot Clinical Intervention as Assessed by EEG and Optical Imaging (Functional Near-Infrared Spectroscopy).

Balconi M, Frezza A, Vanutelli ME.

Front Hum Neurosci. Oct 9;12:
doi: 10.3389/fnhum.2018.eCollection 2018.

Previous research on Schizophrenia (S) revealed anomalies in brain responsiveness during emotion processing, as shown by neuroimaging and electroencephalography (EEG) measures. Nonetheless preserved capacities to explicitly evaluate the emotional significance of affective stimuli in term of valence have been found. The present study applied functional Near-Infrared Spectroscopy (fNIRS) and EEG to explore the spatial and temporal expressions of emotion processing in the brain before (T0) and after (T2) an emotional Neurofeedback (NF) training of patients, assigned to the control or the experimental group. Explicit measures revealed correct identifications

of stimuli emotional valence before (T0) and after (T2) the treatment, while implicit measures (EEG and fNIRS) showed a modulation and increased competencies only after the NF (T2), with more balanced prefrontal activity.

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

Miguel HO, Gonalves F, Cruz S, Sampaio A.

Soc Neurosci. Oct 23:1-

doi: 10.1080/17470919.2018.[Epub ahead of print]

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

Morphine Attenuates fNIRS Signal Associated With Painful Stimuli in the Medial Frontopolar Cortex (medial BA 10).

Peng K, Ycel MA, Steele SC, Bittner EA, Aasted CM, Hoeft MA, Lee A, George EE, Boas DA, Becerra L, Borsook D.

Front Hum Neurosci. Oct 4;12:

doi: 10.3389/fnhum.2018.eCollection 2018.

Functional near infrared spectroscopy (fNIRS) is a non-invasive optical imaging method that provides continuous measure of cortical brain functions. One application has been its use in the evaluation of pain. Previous studies have delineated a deoxygenation process associated with pain in the medial anterior prefrontal region, more specifically, the medial Brodmann Area 10 (BA 10). Such response to painful stimuli has been consistently observed in awake, sedated and anesthetized patients. In this study, we administered oral morphine (15 mg) or placebo to 14 healthy male volunteers with no history of pain or opioid abuse in a crossover double blind design, and performed fNIRS scans prior to and after the administration to assess the effect of morphine on the medial BA 10 pain signal. Morphine is the gold standard for inhibiting nociceptive processing, most well described for brain effects on sensory and emotional regions including the insula, the somatosensory cortex (the primary somatosensory cortex, S1, and the secondary somatosensory cortex, S2), and the anterior cingulate cortex (ACC). Our results showed an attenuation effect of morphine on the fNIRS-measured pain signal in the medial BA 10, as well as in the contralateral S1 (although observed in a smaller number of subjects). Notably, the extent of signal attenuation corresponded with the temporal profile of the reported plasma concentration for the drug. No clear attenuation by morphine on the medial BA 10 response to innocuous stimuli was observed. These results provide further evidence for the role of medial BA 10 in the processing of pain, and also suggest that fNIRS may be used as an objective measure of drug-brain profiles independent of subjective reports.

Adaptive algorithm utilizing acceptance rate for eliminating noisy epochs in block-design functional near-infrared spectroscopy data: application to study in attention deficit/hyperactivity disorder children.

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

Neurophotonics. Oct;5(4):

doi: 10.1117/1.NPh.5.4.Epub 2018 Oct 11.

Erratum in Neurophotonics. 2018 Oct;5(4):049801.

Canonical correlation analysis of brain prefrontal activity mea-

sured by functional near infra-red spectroscopy (fNIRS) during a moral judgment task.

Dashtestani H, Zaragoza R, Pirsiavash H, Knutson KM, Kermanian R, Cui J, Harrison JD Jr, Halem M, Gandjbakhche A.

Behav Brain Res. Feb 1;359:73-

doi: 10.1016/j.bbr.2018.10.Epub Oct 19.

Individuals differ in the extent to which they make decisions in different moral dilemmas. In this study, we investigated the relationship between functional brain activities during moral decision making and psychopathic personality traits in a healthy population. We measured the hemodynamic activities of the brain by functional near-infrared spectroscopy (fNIRS). FNIRS is an evolving non-invasive neuroimaging modality which is relatively inexpensive, patient friendly and robust to subject movement. Psychopathic traits were evaluated through a self-report questionnaire called the Psychopathic Personality Inventory Revised (PPI-R). We recorded functional brain activities of 30 healthy subjects while they performed a moral judgment (MJ) task. Regularized canonical correlation analysis (R-CCA) was applied to find the relationships between activation in different regions of prefrontal cortex (PFC) and the core psychopathic traits. Our results showed a significant canonical correlation between PFC activation and PPI-R content scale (PPI-R-CS). Specifically, coldheartedness and carefree non-planfulness were the only PPI-R-CS factors that were highly correlated with PFC activation during personal (emotionally salient) MJ, while Machiavellian egocentricity, rebellious nonconformity, coldheartedness, and carefree non-planfulness were the core traits that exhibited the same dynamics as PFC activation during impersonal (more logical) MJ. Furthermore, ventromedial prefrontal cortex (vmPFC) and left lateral PFC were the most positively correlated regions with PPI-R-CS traits during personal MJ, and the right vmPFC and right lateral PFC in impersonal MJ.

Functionally dissociating ventro-dorsal components within the rostro-caudal hierarchical organization of the human prefrontal cortex.

Schumacher FK, Schumacher LV, Schelter BO, Kaller CP.

Neuroimage. Jan 15;185:398-

doi: 10.1016/j.neuroimage.2018.10.Epub Oct 19.

Cognitive control is proposed to rely on a rostral-to-caudal hierarchy of neural processing within the prefrontal cortex (PFC), with more rostral

parts exerting control over more caudal parts. Anatomical and functional data suggest that this hierarchical organization of the PFC may be separated into a ventral and a dorsal component. Furthermore, recent studies indicate that the apex of the hierarchy resides within the mid-lateral rather the rostral PFC. However, investigating the hierarchical aspect of rostro-to-caudal processing requires quantification of the directed interactions between PFC regions. Using functional near-infrared spectroscopy (fNIRS) in a sample of healthy young adults we analyzed directed interactions between rostral and caudal PFC during passive watching of nature documentaries. Directed coherence (DC) as a measure of directed interaction was computed pairwise between 38 channels evenly distributed over the lateral prefrontal convexity. Results revealed an overall predominance of rostral-to-caudal directed interactions in the PFC that further dissociated along a ventro-dorsal axis: Dorsal regions exerted stronger rostro-caudally directed interactions on dorsal than on ventral regions and vice versa. Interactions between ventral and dorsal PFC were stronger from ventral to dorsal areas than vice versa. Results further support the notion that the mid-dorsolateral PFC constitutes the apex of the prefrontal hierarchy. Taken together these data provide novel evidence for parallel dorsal and ventral streams within the rostro-caudal hierarchical organization of the PFC. FNIRS-based analyses of directed interactions put forward a new perspective on the functional architecture of the prefrontal hierarchy and complement previous insights from functional magnetic resonance imaging.

Wavelet-based method for removing global physiological noise in functional near-infrared spectroscopy.

Duan L, Zhao Z, Lin Y, Wu X, Luo Y, Xu P.

Biomed Opt Express. Jul 24;9(8):3805-
doi: 10.1364/BOE.9.003805. eCollection Aug 1.

Functional near-infrared spectroscopy (fNIRS) is a fast-developing non-invasive functional brain imaging technology widely used in cognitive neuroscience, clinical research and neural engineering. However, it is a challenge to effectively remove the global physiological noise in the fNIRS signal. The global physiological noise in fNIRS arises from multiple physiological origins in both superficial tissues and the brain. It has complex temporal, spatial and frequency characteristics, casting significant influence on the results. In the present study, we developed a novel wavelet-based method for fNIRS global physiological noise removal. The method is data-driven and does

not rely on any additional hardware or subjective noise component selection procedure. It consists of two steps. Firstly, we use wavelet transform coherence to automatically detect the time-frequency points contaminated by the global physiological noise. Secondly, we decompose the fNIRS signal by using the wavelet transform, and then suppress the wavelet energy of the contaminated time-frequency points. Finally, we transform the signal back to a time series. We validated the method by using simulation and real data at both task- and resting-state. The results showed that our method can effectively remove the global physiological noise from the fNIRS signal and improve the spatial specificity of the task activation and the resting-state functional connectivity pattern.

Novel analysis of fNIRS acquired dynamic hemoglobin concentrations: application in young children with autism spectrum disorder.

Li Y, Jia H, Yu D.

Biomed Opt Express. Jul 13;9(8):3694-
doi: 10.1364/BOE.9.003694. eCollection Aug 1.

A novel analysis of the spatial complexity of functional connectivity (SCFC) was proposed to investigate the spatial complexity of multiple dynamic functional connectivity series in an fNIRS study, using an approach combining principal component analysis and normalized entropy. The analysis was designed to describe the complex spatial features of phase synchrony based dynamic functional connectivity (dFC), which are unexplained in traditional approaches. The feasibility and validity of this method were verified in a sample of young patients with autism spectrum disorders (ASD). Our results showed that there were information exchange deficits in the right prefrontal cortex (PFC) of children with ASD, with markedly higher interregion SCFCs between the right PFC and other brain regions than those of normal controls. Furthermore, the global SCFC was significantly higher in young patients with ASD, along with considerably higher intraregion SCFCs in the prefrontal and temporal lobes which represents more diverse information exchange in these areas. The study suggests a novel method to analyze the fNIRS required dynamic hemoglobin concentrations by using concepts of SCFC. Moreover, the clinical results extend our understanding of ASD pathology, suggesting the crucial role of the right PFC during the information exchange process.

WearLight: Toward a Wearable, Configurable Functional NIR Spectroscopy System for Noninvasive Neuroimaging.

Saikia MJ, Besio WG, Mankodiya K.

IEEE Trans Biomed Circuits Syst. Feb;13(1):91-
doi: 10.1109/TBCAS.2018.Epub Oct 15.
DOI: 10.1109/TBCAS.2018.2876089 PMID: 30334769

Objective assessment of surgical skill transfer using non-invasive brain imaging.

Nemani A, Kruger U, Cooper CA, Schwaitzberg SD, Intes X, De S.

Surg Endosc. Oct
doi: 10.1007/s00464-018-6535-z. [Epub ahead of print]

BACKGROUND: Physical and virtual surgical simulators are increasingly being used in training technical surgical skills. However, metrics such as completion time or subjective performance checklists often show poor correlation to transfer of skills into clinical settings. We hypothesize that non-invasive brain imaging can objectively differentiate and classify surgical skill transfer, with higher accuracy than established metrics, for subjects based on motor skill levels. STUDY DESIGN: 18 medical students at University at Buffalo were randomly assigned into control, physical surgical trainer, or virtual trainer groups. Training groups practiced a surgical technical task on respective simulators for 12 consecutive days. To measure skill transfer post-training, all subjects performed the technical task in an ex-vivo environment. Cortical activation was measured using functional near-infrared spectroscopy (fNIRS) in the prefrontal cortex, primary motor cortex, and supplementary motor area, due to their direct impact on motor skill learning. RESULTS: Classification between simulator trained and untrained subjects based on traditional metrics is poor, where misclassification errors range from 20 to 41%. Conversely, fNIRS metrics can successfully classify physical or virtual trained subjects from untrained subjects with misclassification errors of 2.2% and 8.9%, respectively. More importantly, untrained subjects are successfully classified from physical or virtual simulator trained subjects with misclassification errors of 2.7% and 9.1%, respectively. CONCLUSION: fNIRS metrics are significantly more accurate than current established metrics in classifying different levels of surgical motor skill transfer. Our approach brings robustness, objectivity, and accuracy in

validating the effectiveness of future surgical trainers in translating surgical skills to clinically relevant environments.

Investigation of the Pattern of the Hemodynamic Response as Measured by Functional Near-Infrared Spectroscopy (fNIRS) Studies in Newborns, Less Than a Month Old: A Systematic Review.

de Roever I, Bale G, Mitra S, Meek J, Robertson NJ, Tachtsidis I.

Front Hum Neurosci. Oct 2;12:
doi: 10.3389/fnhum.2018.eCollection 2018.

It has been 20 years since functional near-infrared spectroscopy (fNIRS) was first used to investigate the evoked hemodynamic response to a stimulus in newborns. The hemodynamic response to functional activation is well-established in adults, with an observed increase in concentration change of oxygenated hemoglobin (?[HbO2]) and decrease in deoxygenated hemoglobin (?[HHb]). However, functional studies in newborns have revealed a mixed response, particularly with ?[HHb] where an inconsistent change in direction is observed. The reason for this heterogeneity is unknown, with potential explanations arising from differing physiology in the developing brain, or differences in instrumentation or methodology. The aim of this review is to collate the findings from studies that have employed fNIRS to monitor cerebral hemodynamics in term newborn infants aged 1 day-1 month. A total of 46 eligible studies were identified; some studies investigated more than one stimulus type, resulting in a total of 51 reported results. The NIRS parameters reported varied across studies with 50/51 cases reporting ?[HbO2], 39/51 reporting ?[HHb], and 13/51 reporting total hemoglobin concentration ?[HbT] (?[HbO2] + ?[HHb]). However, of the 39 cases reporting ?[HHb] in graphs or tables, only 24 studies explicitly discussed the response (i.e., direction of change) of this variable. In the studies where the fNIRS responses were discussed, 46/51 cases observed an increase in ?[HbO2], 7/51 observed an increase or varied ?[HHb], and 2/51 reported a varied or negative ?[HbT]. An increase in ?[HbO2] and decrease or no change in ?[HHb] was observed in 15 studies. By reviewing this body of literature, we have identified that the majority of research articles reported an increase in ?[HbO2] across various functional tasks and did not report the response of ?[HHb]. Confirming the normal, healthy hemodynamic response in newborns will allow identification of unhealthy patterns and their association to normal neurodevelopment.

Light up ADHD: II. Neuropharmacological effects measured by near infrared spectroscopy: is there a biomarker?

Grazioli S, Mauri M, Crippa A, Maggioni E, Molteni M, Brambilla P, Nobile M.

J Affect Disord. Feb 1;244:100-
doi: 10.1016/j.jad.2018.10.Epub Oct 9.

BACKGROUND: Attention deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by deficits in self-controlling attention, behavior, and emotions. In recent years, noninvasive optical techniques, such as near infrared spectroscopy (NIRS), have been used to measure the neural correlates of pharmacological-therapy outcomes in children and adolescents with ADHD. METHODS: We reviewed a short series of articles that investigated the results of functional NIRS (fNIRS) on developmental-age ADHD. The review was limited to fNIRS studies that investigated the cortical responses that occurred during neuropsychological tasks in ADHD patients who received methylphenidate or atomoxetine. RESULTS: The majority of the reviewed studies revealed the presence of increased oxygenated hemoglobin concentrations in the prefrontal cortex following pharmacotherapy in ADHD samples. A higher frequency of right-lateralized results was found. LIMITATIONS: The considered studies are characterized by substantial methodological heterogeneity in terms of the patients' medication status and washout period, explored cerebral regions, and neuropsychological tasks. CONCLUSIONS: fNIRS seems to be a promising tool for the detection of pharmacological-treatment biomarkers in samples of children and adolescents with ADHD.

Holistic cognitive and neural processes: a fNIRS-hyperscanning study on interpersonal sensorimotor synchronization.

Dai R, Liu R, Liu T, Zhang Z, Xiao X, Sun P, Yu X, Wang D, Zhu C.

Soc Cogn Affect Neurosci. Nov 8;13(11):1141-
doi: 10.1093/scan/nsy090.

Interpersonal sensorimotor synchronization (interpersonal SMS) is the foundation of complex human social interaction. Previous studies primarily focused on the individual cognitive processes of interpersonal SMS. However, all individuals compose an entire interaction system with emerged holistic properties during interpersonal SMS. Therefore, we proposed the

'holistic cognitive and neural processes' of interpersonal SMS and defined quantitative measurements that included Holistic Correction Gain (HCG), Holistic Timekeeper Variance (HTV) and Holistic Motor Variance (HMV) based on linear error correction model and inter-brain couplings obtained by hyperscanning technique. We performed a joint-tapping experiment including bidirectional and unidirectional conditions using functional near-infrared spectroscopy (fNIRS) hyperscanning to evaluate effects of these holistic processes on synchronization performance. We found that the dyads' performance highly correlated with the integrated effect of holistic cognitive processes in both conditions. Each holistic cognitive process played different roles in interpersonal SMS. HCG was critical to maintain synchronization. HTV related to mentalizing others' behavior. Holistic neural process, the inter-brain coupling of right prefrontal cortex (PFC), was significantly different between bidirectional and unidirectional conditions, which suggested the existence of neural markers at holistic level in interpersonal SMS.

Cross-section and feasibility study on the non-invasive evaluation of muscle hemodynamic responses in Duchenne muscular dystrophy by using a near-infrared diffuse optical technique.
Weng WC, Chen JC, Lee CY, Lin CW, Lee WT, Shieh JY, Wang CC, Chuang CC.
Biomed Opt Express. Sep 12;9(10):4767-
doi: 10.1364/BOE.9.004767. eCollection Oct 1.

Duchenne muscular dystrophy (DMD) is an X-linked debilitating muscular disease that may decrease nitric oxide (NO) production and lead to functional muscular ischemia. Currently, the 6-minute walk test (6-MWT) and the North Star Ambulatory Assessment (NSAA) are the primary outcome measures in clinical trials, but they are severely limited by the subjective consciousness and mood of patients, and can only be used in older and ambulatory boys. This study proposed using functional near-infrared spectroscopy (fNIRS) to evaluate the dynamic changes in muscle hemodynamic responses (gastrocnemius and forearm muscle) during a 6-MWT and a venous occlusion test (VOT), respectively. Muscle oxygenation of the forearm was evaluated non-invasively before, during and after VOT in all participants (included 30 DMD patients and 30 age-matched healthy controls), while dynamic muscle oxygenation of gastrocnemius muscle during 6-MWT was determined in ambulatory participants (n = 18) and healthy controls (n = 30). The results reveal that impaired muscle oxygenation was observed

during 6-MWT in DMD patients that may explain why the DMD patients walked shorter distances than healthy controls. Moreover, the results of VOT implied that worsening muscle function was associated with a lower supply of muscle oxygenation and may provide useful information on the relationship between muscular oxygen consumption and supply for the clinical diagnosis of DMD. Therefore, the method of fNIRS with VOT possesses great potential in future evaluations of DMD patients that implies a good feasibility for clinical application such as for monitoring disease severity of DMD.

Crucial aspects for the use of silicon photomultiplier devices in continuous wave functional near-infrared spectroscopy.

Maira G, Mazzillo M, Libertino S, Fallica G, Lombardo S.

Biomed Opt Express. Sep 7;9(10):4679-

doi: 10.1364/BOE.9.004679. eCollection Oct 1.

In this work, we investigate some major issues for the use of silicon photomultiplier (SiPM) devices in continuous wave functional near-infrared spectroscopy (CW fNIRS). We analyzed the after-pulsing effect, proposing the physical mechanism causing it, and determining its relevance for CW fNIRS. We studied the SiPM transients occurring as the SiPM device goes from the dark (LED in off state) to the illumination (LED in on state) conditions, and vice-versa. Finally, we studied the SiPM SNR in standard CW fNIRS operation.

Effect of baseline brain activity on response to low-frequency rTMS/intensive occupational therapy in poststroke patients with upper limb hemiparesis: a near-infrared spectroscopy study.

Tamashiro H, Kinoshita S, Okamoto T, Urushidani N, Abo M.

Int J Neurosci. Nov 26:1-

doi: 10.1080/00207454.2018.[Epub ahead of print]

BACKGROUND: The beneficial effects of the combination therapy of low-frequency repetitive transcranial magnetic stimulation of nonlesional hemisphere and intensive occupational therapy (LF-rTMS/OT) on upper limb hemiparesis have been well established in poststroke patients. However, there is no information on the effect of brain activity on LF-rTMS/OT

treatment outcome. METHOD: A total of 59 poststroke patients with upper limb hemiparesis received 15-day LF-rTMS/OT. Motor function of the affected upper limb was evaluated before and after the treatment. We also conducted functional near-infrared spectroscopy (fNIRS) before the treatment and calculated the laterality index (LI) based on the change in oxyhemoglobin in the primary sensorimotor cortex and supplementary motor cortex. The correlation between LI before LF-rTMS/OT and observed improvement in upper limb motor function was analyzed. RESULTS: Motor recovery was significantly more pronounced in patients with unaffected hemisphere dominance in both hemispheres (LI of -1 to 0) than in those with affected hemisphere dominance in the lesional hemisphere (LI of 0 to 1). There was a significant negative correlation between LI and improvement in upper limb motor function. DISCUSSION: The results demonstrated that patients with a shift in brain activity to the noninjured cerebral cortex exhibited better motor recovery following LF-rTMS/OT. The findings suggest that evaluation of brain asymmetry before LF-rTMS/OT with fNIRS can help predict the response to LF-rTMS/OT.

Dry Electrode-based Fully Isolated EEG/fNIRS Hybrid Brain-monitoring System.

Lee S, Shin Y, Kumar A, Kim M, Lee HN.

IEEE Trans Biomed Eng. Aug

doi: 10.1109/TBME.2018.[Epub ahead of print]

DOI: 10.1109/TBME.2018.2866550 PMID: 30307848

Functional near-infrared spectroscopy in the evaluation of urban rail transit drivers' mental workload under simulated driving conditions.

Li LP, Liu ZG, Zhu HY, Zhu L, Huang YC.

Ergonomics. Jan 27:1-

doi: 10.1080/00140139.2018.[Epub ahead of print]

The objective of this study is to investigate the potential of functional near-infrared spectroscopy (fNIRS) combined with heart rate variability indices, for the evaluation of the mental workload of urban rail transit drivers under simulated driving conditions, particularly during task engagement and disengagement. Experienced metro drivers wearing fNIRS monitoring

systems were asked to drive for 90?min in a professional metro driving simulator. Workload stimulus tasks were added and an n-back task (n?=?3) was implemented to induce workload in the simulated driving experiment. Experimental results indicate that fNIRS are sensitive to mental workload and reliable for discriminating the degree of mental workload. Research findings demonstrate the feasibility and reliability of fNIRS as a tool for real-time evaluating and monitoring driver mental workload along with task factors from a perspective of brain activations during simulated or actual driving. Practitioner Summary: This study provides evidence for the potential of functional near-infrared spectroscopy (fNIRS) for the evaluation of the mental workload of urban rail transit drivers under simulated driving conditions. The first fNIRS application to mental workload evaluation in the field of urban rail transportation helps companies develop reasonable shiftwork schedule and ensure operation safety.

Concurrent mapping of brain activation from multiple subjects during social interaction by hyperscanning: a mini-review.
Wang MY, Luan P, Zhang J, Xiang YT, Niu H, Yuan Z.
Quant Imaging Med Surg. Sep;8(8):819-
doi: 10.21037/qims.2018.09.07.

Social interaction plays an essential role in acquiring knowledge and developing our own personalities in our daily life. Meanwhile, functional magnetic resonance imaging (fMRI)-, electroencephalograph (EEG)-, and functional near inferred spectroscopy (fNIRS)-hyperscanning, enables us to concurrently map brain activation from two or more participants who are engaged in social interaction simultaneously. In this review, we first highlight the recent technologies advances and the most significant findings towards social interaction by using the hyperscanning method. In addition, we also illustrate several well-designed hyperscanning tasks that have been extensively adopted for the study of social interaction. Basically, hyperscanning contains six categories of experimental paradigms that can track the interactive neural process of interest. Furthermore, it contains two main elucidated neural systems which are involved in social interaction, including the mirror neuron system (MNS) and mentalizing system (MS). Finally, future research directions and clinical implications that are associated with hyperscanning are also highlighted and discussed.

Cortical correlates of speech intelligibility measured using functional near-infrared spectroscopy (fNIRS).

Lawrence RJ, Wiggins IM, Anderson CA, Davies-Thompson J, Hartley DEH.

Hear Res. Dec;370:53-
doi: 10.1016/j.heares.2018.09.Epub Sep 25.

Functional neuroimaging has identified that the temporal, frontal and parietal cortex support core aspects of speech processing. An objective measure of speech intelligibility based on cortical activation in these brain regions would be extremely useful to speech communication and hearing device applications. In the current study, we used noise-vocoded speech to examine cortical correlates of speech intelligibility in normally-hearing listeners using functional near-infrared spectroscopy (fNIRS), a non-invasive, neuroimaging technique that is fully-compatible with hearing devices, including cochlear implants. In twenty-three normally-hearing adults we measured (1) activation in superior temporal, inferior frontal and inferior parietal cortex bilaterally and (2) behavioural speech intelligibility. Listeners heard noise-vocoded sentences targeting five equally spaced levels of intelligibility between 0 and 100% correct. Activation in superior temporal regions increased linearly with intelligibility. This relationship appears to have been driven in part by changing acoustic properties across stimulation conditions, rather than solely by intelligibility per se. Superior temporal activation was also predictive of individual differences in intelligibility in a challenging listening condition. Beyond superior temporal cortex, we identified regions in which activation varied non-linearly with intelligibility. For example, in left inferior frontal cortex, activation peaked in response to heavily degraded, yet still somewhat intelligible, speech. Activation in this region was linearly related to response time on a simultaneous behavioural task, suggesting it may contribute to decision making. Our results indicate that fNIRS has the potential to provide an objective measure of speech intelligibility in normally-hearing listeners. Should these results be found to apply similarly in the case of individuals listening through a cochlear implant, fNIRS would demonstrate potential for a clinically useful measure not only of speech intelligibility, but also of listening effort.

Interpersonal brain synchronization associated with working alliance during psychological counseling.

Zhang Y, Meng T, Hou Y, Pan Y, Hu Y.

Psychiatry Res Neuroimaging. Dec 30;282:103-

doi: 10.1016/j.pscychresns.2018.09.Epub Sep 28.

The mechanisms underlying behavioral synchrony during psychological counseling are not clear. Recent research has provided evidence that pervasive synchrony is associated with interpersonal brain synchronization (IBS) and possibly contributes to the positive working alliance-the degree to which the counseling dyads engage in collaborative and purposive work. Our study explored the IBS between the clients and the counselors using functional near-infrared spectroscopy (fNIRS)-based hyperscanning. Thirty-four participants (as clients) were randomly assigned either to the psychological counseling group or to the chatting group; three female professional counselors provided them with 40 minutes of psychological counseling or chatting. We found better working alliances and increased IBS in the right temporoparietal junction (rTPJ) between clients and counselors during psychological counseling (versus chatting). Such IBS also correlated with the bond of working alliance. To our knowledge, our work represents the first demonstration of fNIRS-hyperscanning measurements for synchronous brain activity between the clients and counselors. This study refines the neural explanation of behavioral synchrony during psychological counseling.

Hemispheric mPFC asymmetry in decision making under ambiguity and risk: An fNIRS study.

Li Y, Chen R, Zhang S, Turel O, Bechara A, Feng T, Chen H, He Q.

Behav Brain Res. Feb 1;359:657-
doi: 10.1016/j.bbr.2018.09.Epub Oct 1.

The Iowa Gambling Task (IGT) is a commonly used task for testing decision-making under ambiguity (the early stage) and risk (the late stage). However, differences between the temporal dynamic signals underlying these two types of decision-making as well as the hemispheric specificity of decision making during the IGT remain unknown. The present study sought to address this gap by focusing on the medial prefrontal cortex (mPFC), which plays an important role in decision-making across life domains. We used functional near-infrared spectroscopy (fNIRS) with high spatial and temporal resolution and measured oxy-hemoglobin concentration within the mPFC in 25 healthy participants who performed the IGT. Results showed that there are different activations of the right and left hemispheres of the mPFC during the different stages of IGT and types of decisions. This implies that the left and right mPFC can have different patterns of involvement in decision making, at least in IGT decisions, including making good (low risk)

and bad (high risk) choices, under ambiguity and under risk conditions.

Reducing auditory verbal hallucinations by means of fNIRS neurofeedback - A case study with a paranoid schizophrenic patient.

Storchak H, Hudak J, Haeussinger FB, Rosenbaum D, Fallgatter AJ, Ehlis AC.

Schizophr Res. Sep pii: S0920-9964(18)30576-
doi: 10.1016/j.schres.2018.09.[Epub ahead of print]
DOI: 10.1016/j.schres.2018.09.018 PMID: 30269928

The effects of CACNA1C gene polymorphism on prefrontal cortex in both schizophrenia patients and healthy controls.

Zhang Z, Wang Y, Zhang Q, Zhao W, Chen X, Zhai J, Chen M, Du B, Deng X, Ji F, Wang C, Xiang Y, Li D, Wu H, Dong Q, Chen C, Li J.

Schizophr Res. Sep pii: S0920-9964(18)30557-
doi: 10.1016/j.schres.2018.09.[Epub ahead of print]

CACNA1C gene polymorphism rs2007044 has been reported to be associated with schizophrenia, but its underlying brain mechanism is not clear. First, we conducted an exploratory functional magnetic resonance imaging (fMRI) study using an N-BACK task and a Stroop task in 194 subjects (55 schizophrenia patients and 139 healthy controls). Our whole brain analysis found that the risk allele was associated with reduced activation of the left inferior frontal gyrus (IFG) during the Stroop task (cluster size = 390 voxels, $P < 0.05$ TFCE-FWE corrected; peak MNI coordinates: x = -57, y = -6, z = 30). We also conducted a functional near-infrared spectroscopy (fNIRS) study using the same Stroop task in an independent sample of 126 healthy controls to validate the fMRI finding. Our repeated-measures ANCOVA on the six channels (20, 27, 33, 34, 40 and 46) within the left IFG also found significant result. The polymorphism rs2007044 showed significant effect on the oxy-Hb data ($F = 5.072$, $P = 0.026$) and showed significant interaction effect with channels on the deoxy-Hb data ($F = 2.841$, $P = 0.015$). Taken together, results of this study suggested that rs2007044 could affect the activation of the left IFG, which was a possible brain mechanism underlying the association between CACNA1C gene polymorphism and schizophrenia.

Brain asymmetry in directing attention during dichotic listening test: An fNIRS study.

Eskicioglu E, Taslica S, Narin B, Guducu C, Oniz A, Ozgoren M.

Laterality. Sep 27:1-
doi: 10.1080/1357650X.2018.[Epub ahead of print]

In a classical dichotic listening paradigm, besides auditory brain asymmetry, cognitive functions such as attention and conflict resolution play a major role. The aim of this study is to reveal the possible haemodynamic mechanisms of higher attentional performance in prefrontal cortex during dichotic listening test. Twenty-six healthy participants underwent a dichotic listening task in three sessions; non-forced attention, attention focused to right ear, and attention focused to left ear. In each session, haemodynamic activity of prefrontal brain area was recorded using functional near-infrared spectroscopy (fNIRS). Effects of focused attention and performance level of the task on oxy-, deoxy-, and total haemoglobin levels were investigated. Oxy- and total haemoglobin levels in right prefrontal regions during forced-right and forced-left sessions were significantly higher than levels of the non-forced session. This might be an indicator of inhibition and orienting attentional functions of right inferior frontal gyrus. High performers had significantly higher deoxyhaemoglobin levels in the forced-left session compared to the non-forced session, while low performers' deoxyhaemoglobin levels did not differ among these sessions. Observing this difference only in the forced-left session but not in the forced-right session might suggest conflict resolution in top-down and bottom-up processes during the forced-left session for right-handed participants.

Reduced motor cortex inhibition and a 'cognitive-first' prioritisation strategy for older adults during dual-tasking.

Corp DT, Youssef GJ, Clark RA, Gomes-Osman J, Ycel MA, Oldham SJ, Aldraiwiesh S, Rice J, Pascual-Leone A, Rogers MA.

Exp Gerontol. Nov;113:95-
doi: 10.1016/j.exger.2018.09.Epub 2018 Sep 24.

It is well established that older adults are less able to perform attentionally demanding motor tasks, placing them at greater risk of accident-related injury. The primary purpose of this study was to investigate whether the interplay between prefrontal and motor cortex activity could predict such age-

related performance deficits. Using a dual-task (DT) paradigm, 15 younger and 15 older adults participated in experiment 1, where brain activity was simultaneously measured using functional near infrared spectroscopy (fNIRS) and transcranial magnetic stimulation (TMS). Experiment 1 demonstrated poorer performance for the older group across a range of DTs combining visuomotor arm tracking with a secondary cognitive or motor task. Interestingly however, older adults' DT performance error was isolated to the motor component of DTs. TMS data revealed reduced motor cortex (M1) inhibition during DTs for older adults, and a trend for this correlating with poorer performance. In contrast, poorer performing younger adults showed significantly higher M1 inhibition. Experiment 2 was conducted given a high amount of movement artifact in experiment 1 fNIRS data. Using fNIRS to measure prefrontal, premotor, and motor cortex activity in an additional 15 older adults, we found no evidence of an interplay between these regions predicting DT performance. Nevertheless, performance data replicated experiment 1 in showing that DT error was isolated to motor tasks in older adults, with no significant cognitive task error. Overall, this study shows that older adults seemed to adopt a 'cognitive-first' prioritisation strategy during the DTs involved in our study, and that deficits in DT performance may be related to the modulation of M1 inhibitory mechanisms. We propose that clinicians advise older adults to allocate greater attention to motor tasks during activities where they may be at risk of accident-related injury.

Online classification of imagined speech using functional near-infrared spectroscopy signals.

Rezazadeh Sereshkeh A, Yousefi R, Wong AT, Chau T.

J Neural Eng. Feb;16(1):
doi: 10.1088/1741-2552/aae4bEpub Sep 27.

OBJECTIVE: Most brain-computer interfaces (BCIs) based on functional near-infrared spectroscopy (fNIRS) require that users perform mental tasks such as motor imagery, mental arithmetic, or music imagery to convey a message or to answer simple yes or no questions. These cognitive tasks usually have no direct association with the communicative intent, which makes them difficult for users to perform. APPROACH: In this paper, a 3-class intuitive BCI is presented which enables users to directly answer yes or no questions by covertly rehearsing the word 'yes' or 'no' for 15 s. The BCI also admits an equivalent duration of unconstrained rest which constitutes the third discernable task. Twelve participants each completed one offline block

and six online blocks over the course of two sessions. The mean value of the change in oxygenated hemoglobin concentration during a trial was calculated for each channel and used to train a regularized linear discriminant analysis (RLDA) classifier. MAIN RESULTS: By the final online block, nine out of 12 participants were performing above chance (p??<??0.001 using the binomial cumulative distribution), with a 3-class accuracy of 83.8%????9.4%. Even when considering all participants, the average online 3-class accuracy over the last three blocks was 64.1 %????20.6%, with only three participants scoring below chance (p??<??0.001). For most participants, channels in the left temporal and temporoparietal cortex provided the most discriminative information. SIGNIFICANCE: To our knowledge, this is the first report of an online 3-class imagined speech BCI. Our findings suggest that imagined speech can be used as a reliable activation task for selected users for development of more intuitive BCIs for communication.

Distinction of directional coupling in sensorimotor networks between active and passive finger movements using fNIRS.

Lee SH, Jin SH, An J.

Biomed Opt Express. May 31;9(6):2859-
doi: 10.1364/BOE.9.002859. eCollection Jun 1.

The purpose of this study is to investigate cerebral cortex activation during active movement and passive movement by using a functional near-infrared spectroscopy (fNIRS). Tasks were the flexion/extension of the right hand finger by active movement and passive movement. Oxy-hemoglobin concentration changes calculated from fNIRS and analyzed the activation and connectivity so as to understand dynamical brain relationship. The results demonstrated that the brain activation in passive movements is similar to motor execution. During active movement, the estimated causality patterns showed significant causality value from the supplementary motor area (SMA) to the primary motor cortex (M1). During the passive movement, the causality from the primary somatosensory cortex (S1) to the primary motor cortex (M1) was stronger than active movement. These results demonstrated that active and passive movements had a direct effect on the cerebral cortex but the stimulus pathway of active and passive movement is different. This study may contribute to better understanding how active and passive movements can be expressed into cortical activation by means of fNIRS.

Navigation in Real-World Environments: New Opportunities Afforded by Advances in Mobile Brain Imaging.

Park JL, Dudchenko PA, Donaldson DI.

Front Hum Neurosci. Sep 11;12:
doi: 10.3389/fnhum.2018.00361. eCollection 2018.

A central question in neuroscience and psychology is how the mammalian brain represents the outside world and enables interaction with it. Significant progress on this question has been made in the domain of spatial cognition, where a consistent network of brain regions that represent external space has been identified in both humans and rodents. In rodents, much of the work to date has been done in situations where the animal is free to move about naturally. By contrast, the majority of work carried out to date in humans is static, due to limitations imposed by traditional laboratory based imaging techniques. In recent years, significant progress has been made in bridging the gap between animal and human work by employing virtual reality (VR) technology to simulate aspects of real-world navigation. Despite this progress, the VR studies often fail to fully simulate important aspects of real-world navigation, where information derived from self-motion is integrated with representations of environmental features and task goals. In the current review article, we provide a brief overview of animal and human imaging work to date, focusing on commonalties and differences in findings across species. Following on from this we discuss VR studies of spatial cognition, outlining limitations and developments, before introducing mobile brain imaging techniques and describe technical challenges and solutions for real-world recording. Finally, we discuss how these advances in mobile brain imaging technology, provide an unprecedented opportunity to illuminate how the brain represents complex multifaceted information during naturalistic navigation.

The role of prefrontal cortex in a moral judgment task using functional near-infrared spectroscopy.

Dashtestani H, Zaragoza R, Kermanian R, Knutson KM, Halem M, Casey A, Shahni Karamzadeh N, Anderson AA, Boccara AC, Gandjbakhche A.

Brain Behav. Nov;8(11):e
doi: 10.1002/brb3.Epub Sep 25.

BACKGROUND: Understanding the neural basis of moral judgment

(MJ) and human decision-making has been the subject of numerous studies because of their impact on daily life activities and social norms. Here, we aimed to investigate the neural process of MJ using functional near-infrared spectroscopy (fNIRS), a noninvasive, portable, and affordable neuroimaging modality. METHODS: We examined prefrontal cortex (PFC) activation in 33 healthy participants engaging in MJ exercises. We hypothesized that participants presented with personal (emotionally salient) and impersonal (less emotional) dilemmas would exhibit different brain activation observable through fNIRS. We also investigated the effects of utilitarian and nonutilitarian responses to MJ scenarios on PFC activation. Utilitarian responses are those that favor the greatest good while nonutilitarian responses favor moral actions. Mixed effect models were applied to model the cerebral hemodynamic changes that occurred during MJ dilemmas. RESULTS AND CONCLUSIONS: Our analysis found significant differences in PFC activation during personal versus impersonal dilemmas. Specifically, the left dorsolateral PFC was highly activated during impersonal MJ when a nonutilitarian decision was made. This is consistent with the majority of relevant fMRI studies, and demonstrates the feasibility of using fNIRS, with its portable and motion tolerant capacities, to investigate the neural basis of MJ dilemmas.

The neurodevelopmental precursors of altruistic behavior in infancy.

Grossmann T, Missana M, Krol KM.

PLoS Biol. Sep 25;16(9):e
doi: 10.1371/journal.pbio.2005281. eCollection Sep.

Altruistic behavior is considered a key feature of the human cooperative makeup, with deep ontogenetic roots. The tendency to engage in altruistic behavior varies between individuals and has been linked to differences in responding to fearful faces. The current study tests the hypothesis that this link exists from early in human ontogeny. Using eye tracking, we examined whether attentional responses to fear in others at 7 months of age predict altruistic behavior at 14 months of age. Our analysis revealed that altruistic behavior in toddlerhood was predicted by infants' attention to fearful faces but not happy or angry faces. Specifically, infants who showed heightened initial attention to (i.e., prolonged first look) followed by greater disengagement (i.e., reduced attentional bias over 15 seconds) from fearful faces at 7 months displayed greater prosocial behavior at 14 months of age.

Our data further show that infants' attentional bias to fearful faces and their altruistic behavior was predicted by brain responses in the dorsolateral prefrontal cortex (dlPFC), measured through functional near-infrared spectroscopy (fNIRS). This suggests that, from early in ontogeny, variability in altruistic helping behavior is linked to our responsiveness to seeing others in distress and brain processes implicated in attentional control. These findings critically advance our understanding of the emergence of altruism in humans by identifying responsiveness to fear in others as an early precursor contributing to variability in prosocial behavior.

Cognitive Load Changes during Music Listening and its Implication in Earcon Design in Public Environments: An fNIRS Study.

Jeong E, Ryu H, Jo G, Kim J.

Int J Environ Res Public Health. Sep 21;15(10). pii: E
doi: 10.3390/ijerph15102075.

A key for earcon design in public environments is to incorporate an individual's perceived level of cognitive load for better communication. This study aimed to examine the cognitive load changes required to perform a melodic contour identification task (CIT). While healthy college students (N = 16) were presented with five CITs, behavioral (reaction time and accuracy) and cerebral hemodynamic responses were measured using functional near-infrared spectroscopy. Our behavioral findings showed a gradual increase in cognitive load from CIT1 to CIT3 followed by an abrupt increase between CIT4 (i.e., listening to two concurrent melodic contours in an alternating manner and identifying the direction of the target contour, $p < 0.001$) and CIT5 (i.e., listening to two concurrent melodic contours in a divided manner and identifying the directions of both contours, $p < 0.001$). Cerebral hemodynamic responses showed a congruent trend with behavioral findings. Specific to the frontopolar area (Brodmann's area 10), oxygenated hemoglobin increased significantly between CIT4 and CIT5 ($p < 0.05$) while the level of deoxygenated hemoglobin decreased. Altogether, the findings indicate that the cognitive threshold for young adults (CIT5) and appropriate tuning of the relationship between timbre and pitch contour can lower the perceived cognitive load and, thus, can be an effective design strategy for earcon in a public environment.

Array Designer: automated optimized array design for functional near-infrared spectroscopy.

Brigadoi S, Salvagnin D, Fischetti M, Cooper RJ.

Neurophotonics. Jul;5(3):
doi: 10.1117/1.NPh.5.3.Epub 2018 Sep 13.

The position of each source and detector "optode" on the scalp, and their relative separations, determines the sensitivity of each functional near-infrared spectroscopy (fNIRS) channel to the underlying cortex. As a result, selecting appropriate scalp locations for the available sources and detectors is critical to every fNIRS experiment. At present, it is standard practice for the user to undertake this task manually; to select what they believe are the best locations on the scalp to place their optodes so as to sample a given cortical region-of-interest (ROI). This process is difficult, time-consuming, and highly subjective. Here, we propose a tool, Array Designer, that is able to automatically design optimized fNIRS arrays given a user-defined ROI and certain features of the available fNIRS device. Critically, the Array Designer methodology is generalizable and will be applicable to almost any subject population or fNIRS device. We describe and validate the algorithmic methodology that underpins Array Designer by running multiple simulations of array design problems in a realistic anatomical model. We believe that Array Designer has the potential to end the need for manual array design, and in doing so save researchers time, improve fNIRS data quality, and promote standardization across the field.

Sensory manipulation results in increased dorsolateral prefrontal cortex activation during static postural balance in sedentary older adults: An fNIRS study.

Teo WP, Goodwill AM, Hendy AM, Muthalib M, Macpherson H.

Brain Behav. Oct;8(10):e
doi: 10.1002/brb3.Epub Sep 19.

BACKGROUND: The dorsolateral prefrontal cortex (DLPFC) is involved with allocating attentional resources to maintain postural control. However, it is unknown whether age-related structural and functional declines of the DLPFC may impair postural control during sensory manipulation. In this study, we aim to understand the effects of aging on the DLPFC when sensory cues were removed or presented inaccurately (i.e., increased sensory complexity) during the sensory orientation test (SOT). METHODS: Twenty young (18-25years) and 18 older (66-73years) healthy

adults were recruited to undertake the SOT, which consisted of six conditions aimed at removing or disrupting the visual, vestibular, and proprioceptive senses. During these six SOT conditions, functional near-infrared spectroscopy (fNIRS), consisting of eight transmitter-receiver optode pairs (four channels over the left and right DLPFC), was used to measure hemodynamic responses (i.e., changes in oxy- [O2 Hb] and deoxyhemoglobin [HHb]) from the bilateral DLPFC. RESULTS: Our results show an increase in bilateral DLPFC activation (i.e., increase in O2 Hb and concomitant smaller decrease in HHb) with increasing sensory complexity in both young and older adults. The increase in left and right DLPFC activation during more complex sensory conditions was greater, which was concomitant with reduced balance performance in older adults compared to younger adults. Furthermore, we observed a right lateralized DLPFC activation in younger adults. Finally, a significant positive association was observed between balance performance and increased bilateral DLPFC activation particularly for SOT conditions with greater sensory disruptions. CONCLUSION: Our findings highlight the involvement of the DLPFC in maintaining postural control, particularly during complex sensory tasks, and provide direct evidence for the role of the DLPFC during postural control of a clinically relevant measure of balance.

Modulation of Cortical Activity Induced by High-Frequency Whole-body Vibration Exercise: An fNIRS Study.

Choi DS, Lee HJ, Shin YI, Lee A, Kim HG, Kim YH.

J Sport Rehabil. Sep 17:1-
doi: 10.1123/jsr.2017-[Epub ahead of print]

CONTEXT: Whole-body vibration (WBV) has shown many positive effects on the human body in rehabilitation and clinical settings in which vibration has been used to elicit muscle contractions in spastic and paretic muscles. OBJECTIVE: The purpose of this study was to investigate whether WBV exercise (WBVe) differently modulates the cortical activity associated with motor and prefrontal function based on its frequency. METHODS: Eighteen healthy male adults (mean age: 25.3 2.4 years) participated in this study and performed WBVe (Galileo Advanced plus, Novotec Medical, Pforzheim, Germany) under three different vibration frequency conditions (4-mm amplitude with 10-, 20- and 27-Hz frequencies) and a control condition (0 mm amplitude with 0-Hz frequency). Each condition consisted of two alternating tasks (squatting and standing) every 30 sec for five repetitions. All subjects performed the four conditions in a randomized order. MAIN

OUTCOME MEASURES: Cortical activation during WBVe was measured by relative changes in oxygenated hemoglobin (oxyHb) concentration over the primary motor cortex (M1), premotor cortex (PM), supplementary motor area (SMA), and prefrontal and somatosensory cortices using functional near-infrared spectroscopy (fNIRS). RESULTS: OxyHb concentration was higher during the 27-Hz vibration condition than the control and 10-Hz vibration conditions. Specifically, these changes were pronounced in the bilateral M1s ($p < 0.05$) and right prefrontal cortex ($p < 0.05$). In contrast, no significant changes in oxyHb concentration were observed in any of the cortical areas during the 10-Hz vibration condition compared with control condition. CONCLUSION: This study provides evidence that the motor network and prefrontal cortical areas of healthy adult males can be activated by 27-Hz WBVe. However, WBVe at lower frequencies did not induce significant changes in cortical activation.

Temporal Derivative Distribution Repair (TDDR): A motion correction method for fNIRS.

Fishburn FA, Ludlum RS, Vaidya CJ, Medvedev AV.

Neuroimage. Jan 1;184:171-

doi: 10.1016/j.neuroimage.2018.09.Epub Sep 11.

Functional near-infrared spectroscopy (fNIRS) is an optical neuroimaging technique of growing interest as a tool for investigation of cortical activity. Due to the on-head placement of optodes, artifacts arising from head motion are relatively less severe than for functional magnetic resonance imaging (fMRI). However, it is still necessary to remove motion artifacts. We present a novel motion correction procedure based on robust regression, which effectively removes baseline shift and spike artifacts without the need for any user-supplied parameters. Our simulations show that this method yields better activation detection performance than 5 other current motion correction methods. In our empirical validation on a working memory task in a sample of children 7-15 years, our method produced stronger and more extensive activation than any of the other methods tested. The new motion correction method enhances the viability of fNIRS as a functional neuroimaging modality for use in populations not amenable to fMRI.

Communication of emotion via drumming: dual-brain imag-

ing with functional near-infrared spectroscopy.
Rojiani R, Zhang X, Noah A, Hirsch J.
Soc Cogn Affect Neurosci. Oct 25;13(10):1047-
doi: 10.1093/scan/nsy076.

Nonverbal communication of emotion is essential to human interaction and relevant to many clinical applications, yet it is an understudied topic in social neuroscience. Drumming is an ancient nonverbal communication modality for expression of emotion that has not been previously investigated in this context. We investigate the neural response to live, natural communication of emotion via drumming using a novel dual-brain neuroimaging paradigm. Hemodynamic signals were acquired using whole-head functional near-infrared spectroscopy (fNIRS). Dyads of 36 subjects participated in two conditions, drumming and talking, alternating between 'sending' (drumming or talking to partner) and 'receiving' (listening to partner) in response to emotionally salient images from the International Affective Picture System. Increased frequency and amplitude of drum strikes was behaviorally correlated with higher arousal and lower valence measures and neurally correlated with temporoparietal junction (TPJ) activation in the listener. Contrast comparisons of drumming greater than talking also revealed neural activity in right TPJ. Together, findings suggest that emotional content communicated by drumming engages right TPJ mechanisms in an emotionally and behaviorally sensitive fashion. Drumming may provide novel, effective clinical approaches for treating social-emotional psychopathology.

Somatosensory Response to Trigeminal Stimulation: A Functional Near-Infrared Spectroscopy (fNIRS) Study.
Hucke CI, Pacharra M, Reinders J, van Thriel C.
Sci Rep. Sep 13;8(1):
doi: 10.1038/s41598-018-32147-1.

Functional near-infrared spectroscopy (fNIRS) is an optical imaging technique measuring relative hemodynamic changes in superficial cortical structures. It has successfully been applied to detect a hemodynamic response in the somatosensory cortex evoked by irritating mechanical, electrical, and heat stimulations of limbs or the face. The aim of the current study was to explore the feasibility of fNIRS to detect respective responses evoked by irritating chemical stimulations of the nasal divisions of the trigeminal nerve. In two experiments, healthy subjects were exposed to acetic acid and ethyl acetate presented using a respiration-synchronized olfactometer. Re-

sults demonstrated that fNIRS can detect a signal in both hemispheres after birhinal (experiment 1: n?=?14) and monorhinal (experiment 2: n?=?12) stimulations using acetic acid but not ethyl acetate. This is a first evidence that fNIRS might be a suitable imaging technique to assess chemosensory neuronal correlates in the somatosensory cortex thereby offering a new, portable method to evaluate the irritating properties of certain volatiles in an objective, nonverbal, easy, and comparably inexpensive manner.

Irritability uniquely predicts prefrontal cortex activation during preschool inhibitory control among all temperament domains: A LASSO approach.

Fishburn FA, Hlutkowsky CO, Bemis LM, Huppert TJ, Wakschlag LS, Perlman SB.

Neuroimage. Jan 1;184:68-

doi: 10.1016/j.neuroimage.2018.09.Epub Sep 11.

Temperament, defined as individual variation in the reactivity and regulation of emotional, motor, and attentional processes, has been shown to influence emotional and cognitive development during the preschool period (ages 4-5). While relationships between temperament and neural activity have been investigated previously, these have typically investigated individual temperament dimensions selected ad hoc. Since significant correlations exist between various temperament dimensions, it remains unclear whether these findings would replicate while analyzing all temperament dimensions simultaneously. Using functional near infrared spectroscopy (fNIRS), 4-5-year-old children (N = 118) were administered a Go/No-Go task to assess prefrontal cortex activation during inhibitory control. The relationship between PFC activation and all 15 temperament domains defined by the Children's Behavior Questionnaire (CBQ) was assessed using automatic feature selection via LASSO regression. Results indicate that only the Anger/Frustration dimension was predictive of activation during the inhibitory control task. These findings support previous work showing relationships between irritability and prefrontal activation during executive function and extend those findings by demonstrating the specificity of the activation-irritability relationship among temperament dimensions.

Changes in cerebral activation in individuals with and without

visual vertigo during optic flow: A functional near-infrared spectroscopy study.

Hoppes CW, Sparto PJ, Whitney SL, Furman JM, Huppert TJ.

Neuroimage Clin. Sep 5;20:655-
doi: 10.1016/j.nicl.2018.08.034. eCollection 2018.

Background and purpose: Individuals with visual vertigo (VV) describe symptoms of dizziness, disorientation, and/or impaired balance in environments with conflicting visual and vestibular information or complex visual stimuli. Physical therapists often prescribe habituation exercises using optic flow to treat these symptoms, but it is not known how individuals with VV process the visual stimuli. The primary purpose of this study was to use functional near-infrared spectroscopy (fNIRS) to determine if individuals with VV have different cerebral activation during optic flow compared with control subjects. Methods: Fifteen individuals (5 males and 10 females in each group) with VV seeking care for dizziness and 15 healthy controls (CON) stood in a virtual reality environment and viewed anterior-posterior optic flow. The support surface was either fixed or sway-referenced. Changes in cerebral activation were recorded using fNIRS during periods of optic flow relative to a stationary visual environment. Postural sway of the head and center of mass was recorded using an electromagnetic tracker. Results: Compared with CON, the VV group displayed decreased activation in the bilateral middle frontal regions when viewing optic flow while standing on a fixed platform. Despite both groups having significantly increased activation in most regions while viewing optic flow on a sway-referenced surface, the VV group did not have as much of an increase in the right middle frontal region when viewing unpredictable optic flow in comparison with the CON group. Discussion and conclusions: Individuals with VV produced a pattern of reduced middle frontal cerebral activation when viewing optic flow compared with CON. Decreased activation in the middle frontal regions of the cerebral cortex may represent an alteration in control over the normal reciprocal inhibitory visual-vestibular interaction in visually dependent individuals. Although preliminary, these findings add to a growing body of literature using functional brain imaging to explore changes in cerebral activation in individuals with complaints of dizziness, disorientation, and unsteadiness. Future studies in larger samples should explore if this decreased activation is modified following a rehabilitation regimen consisting of visual habituation exercises.

Symbolic time series analysis of fNIRS signals in brain development assessment.

Liang Z, Minagawa Y, Yang HC, Tian H, Cheng L, Arimitsu T, Takahashi T, Tong Y.

J Neural Eng. Dec;15(6):
doi: 10.1088/1741-2552/aae0cEpub Sep 12.

OBJECTIVE: Assessing an infant's brain development remains a challenge for neuroscientists and pediatricians despite great technological advances. As a non-invasive neuroimaging tool, functional near-infrared spectroscopy (fNIRS) has great advantages in monitoring an infant's brain activity. To explore the dynamic features of hemodynamic changes in infants, in-pattern exponent (IPE), anti-pattern exponent (APE), as well as permutation cross-mutual information (PCMI) based on symbolic dynamics are proposed to measure the phase differences and coupling strength in oxyhemoglobin (HbO) and deoxyhemoglobin (Hb) signals from fNIRS. APPROACH: First, simulated sinusoidal oscillation signals and four coupled nonlinear systems were employed for performance assessments. Hilbert transform based measurements of hemoglobin phase oxygenation and deoxygenation (hPod) and phase-locking index of hPod (hPodL) were calculated for comparison. Then, the IPE, APE and PCMI indices from resting state fNIRS data of preterm, term infants and adults were calculated to estimate the phase difference and coupling of HbO and Hb. All indices' performance was assessed by the degree of monotonicity (DoM). The box plots and coefficients of variation (CV) were employed to assess the measurements and robustness in the results. MAIN RESULTS: In the simulation analysis, IPE and APE can distinguish the phase difference of two sinusoidal oscillation signals. Both hPodL and PCMI can track the strength of two coupled nonlinear systems. Compared to hPodL, the PCMI had higher DoM indices in measuring the coupling of two nonlinear systems. In the fNIRS data analysis, similar to hPod, the IPE and APE can distinguish preterm, term infants, and adults in 0.01-0.05 Hz, 0.05-0.1 Hz, and 0.01-0.1 Hz frequency bands, respectively. PCMI more effectively distinguished the term and preterm infants than hPodL in the 0.05-0.1 Hz frequency band. As symbolic time series measures, the IPE and APE were able to detect the brain developmental changes in subjects of different ages. PCMI can assess the resting-state HbO and Hb coupling changes across different developmental ages, which may reflect the metabolic and neurovascular development. SIGNIFICANCE: The symbolic-based methodologies are promising measures for fNIRS in estimating the brain development, especially in assessing newborns' brain developmental status.

A Motivational Model of BCI-Controlled Heuristic Search.

Cavazza M.

Brain Sci. Aug 31;8(9). pii: E
doi: 10.3390/brainsci8090166.

Several researchers have proposed a new application for human augmentation, which is to provide human supervision to autonomous artificial intelligence (AI) systems. In this paper, we introduce a framework to implement this proposal, which consists of using Brain?Computer Interfaces (BCI) to influence AI computation via some of their core algorithmic components, such as heuristic search. Our framework is based on a joint analysis of philosophical proposals characterising the behaviour of autonomous AI systems and recent research in cognitive neuroscience that support the design of appropriate BCI. Our framework is defined as a motivational approach, which, on the AI side, influences the shape of the solution produced by heuristic search using a BCI motivational signal reflecting the user's disposition towards the anticipated result. The actual mapping is based on a measure of prefrontal asymmetry, which is translated into a non-admissible variant of the heuristic function. Finally, we discuss results from a proof-of-concept experiment using functional near-infrared spectroscopy (fNIRS) to capture prefrontal asymmetry and control the progression of AI computation of traditional heuristic search problems.

Cooperation Makes a Group be More Creative.

Lu K, Xue H, Nozawa T, Hao N.

Cereb Cortex. Sep
doi: 10.1093/cercor/bhy[Epub ahead of print]

This study investigated how cooperative and competitive interaction modes affect the group creative performance. The participants were recruited as dyads to solve 2 problems either demanding divergent thinking (alternative uses task, AUT) or not (object characteristic task, OCT). The dyads solved 1 of the 2 problems in the cooperative mode and the other in the competitive mode. Functional near-infrared spectroscopy (fNIRS)-based hyperscanning was used to record their neural activities in the prefrontal and right temporal-parietal junction (r-TPJ) regions. Results revealed the dyads showed higher AUT fluency, AUT originality, OCT fluency, and cooperation level in the cooperative mode than in the competitive mode. The fNIRS data

revealed increased (task-baseline) interpersonal brain synchronization (IBS) in the right dorsolateral prefrontal cortex (r-DLPFC) and r-TPJ, only for dyads in the AUT/cooperation condition. In both r-DLPFC and r-TPJ, the IBS of dyads in the AUT/cooperation condition was stronger than in the AUT/competition and OCT/cooperation. Moreover, a stronger IBS was evoked between the regions in prefrontal and posterior temporal regions in the AUT/cooperation condition, as compared with the competition mode. These findings suggest that enhanced IBS may underlie the positive effects of cooperation as compared with the competition in terms of group creativity.

Motion Artifact Correction of Multi-Measured Functional Near-Infrared Spectroscopy Signals Based on Signal Reconstruction Using an Artificial Neural Network.

Lee G, Jin SH, An J.

Sensors (Basel). Sep 5;18(9). pii: E
doi: 10.3390/s18092957.

In this paper, a new motion artifact correction method is proposed based on multi-channel functional near-infrared spectroscopy (fNIRS) signals. Recently, wavelet transform and hemodynamic response function-based algorithms were proposed as methods of denoising and detrending fNIRS signals. However, these techniques cannot achieve impressive performance in the experimental environment with lots of movement such as gait and rehabilitation tasks because hemodynamic responses have features similar to those of motion artifacts. Moreover, it is difficult to correct motion artifacts in multi-measured fNIRS systems, which have multiple channels and different noise features in each channel. Thus, a new motion artifact correction method for multi-measured fNIRS is proposed in this study, which includes a decision algorithm to determine the most contaminated fNIRS channel based on entropy and a reconstruction algorithm to correct motion artifacts by using a wavelet-decomposed back-propagation neural network. The experimental data was achieved from six subjects and the results were analyzed in comparing conventional algorithms such as HRF smoothing, wavelet denoising, and wavelet MDL. The performance of the proposed method was proven experimentally using the graphical results of the corrected fNIRS signal, CNR that is a performance evaluation index, and the brain activation map.

Functional near-infrared spectroscopy study of the neural correlates between auditory environments and intellectual work performance.

Hiwa S, Katayama T, Hiroyasu T.

Brain Behav. Oct;8(10):e
doi: 10.1002/brb3.Epub Sep 5.

INTRODUCTION: Many people spend a considerable amount of time performing intellectual activities within auditory environments that affect work efficiency. To investigate auditory environments that improve working efficiency, we investigated the relationship between brain activity and performance of the number memory task in environments with and without white noise using functional near-infrared spectroscopy (fNIRS). METHODS: Twenty-nine healthy subjects (aged 21.91.4years) performed the number memory task in both the white noise and silent environments. Cerebral blood flow changes during the task were measured using an ETG-7100 fNIRS system (Hitachi, Ltd., Tokyo, Japan). The psychological states of the subjects were also estimated by subjective ratings of the pleasantness of the auditory environment. Then, they were divided into three groups based on their task scores. The differences in the cerebral blood flow (CBF) changes, functional connection strength, and the subjects' feelings of pleasantness to the noise between the subject groups were analyzed and discussed. RESULTS: The first group felt that the white noise was pleasant, which strengthened the bilateral functional connections between the brain regions related to the memory task. Therefore, the subjects' task performance improved in the white noise environment. Although the second group felt that the white noise was uncomfortable, the frontal regions related to attention control were more activated in the white noise environment to sustain the task performance in the noisy environment. The third group felt that the white noise was unpleasant, and their CBF decreased in that environment, which was associated with deteriorated task performance. CONCLUSIONS: Task performance was closely related to the subjects' feelings of pleasantness to the noise. The results of the analysis of the CBF changes and functional connectivity suggested that the effects of the white noise on brain activity differed among the three groups.

Recognizing Frustration of Drivers From Face Video Recordings and Brain Activation Measurements With Functional Near-Infrared Spectroscopy.

Ihme K, Unni A, Zhang M, Rieger JW, Jipp M.
Front Hum Neurosci. Aug 17;12:
doi: 10.3389/fnhum.2018.00327. eCollection 2018.

Experiencing frustration while driving can harm cognitive processing, result in aggressive behavior and hence negatively influence driving performance and traffic safety. Being able to automatically detect frustration would allow adaptive driver assistance and automation systems to adequately react to a driver's frustration and mitigate potential negative consequences. To identify reliable and valid indicators of driver's frustration, we conducted two driving simulator experiments. In the first experiment, we aimed to reveal facial expressions that indicate frustration in continuous video recordings of the driver's face taken while driving highly realistic simulator scenarios in which frustrated or non-frustrated emotional states were experienced. An automated analysis of facial expressions combined with multivariate logistic regression classification revealed that frustrated time intervals can be discriminated from non-frustrated ones with accuracy of 62.0% (mean over 30 participants). A further analysis of the facial expressions revealed that frustrated drivers tend to activate muscles in the mouth region (chin raiser, lip pucker, lip pressor). In the second experiment, we measured cortical activation with almost whole-head functional near-infrared spectroscopy (fNIRS) while participants experienced frustrating and non-frustrating driving simulator scenarios. Multivariate logistic regression applied to the fNIRS measurements allowed us to discriminate between frustrated and non-frustrated driving intervals with higher accuracy of 78.1% (mean over 12 participants). Frustrated driving intervals were indicated by increased activation in the inferior frontal, putative premotor and occipito-temporal cortices. Our results show that facial and cortical markers of frustration can be informative for time resolved driver state identification in complex realistic driving situations. The markers derived here can potentially be used as an input for future adaptive driver assistance and automation systems that detect driver frustration and adaptively react to mitigate it.

Oxyhemoglobin changes in the prefrontal cortex in response to cognitive tasks: a systematic review.

Bonetti LV, Hassan SA, Lau ST, Melo LT, Tanaka T, Patterson KK, Reid WD.
Int J Neurosci. Oct 31:1-

doi: 10.1080/00207454.2018.[Epub ahead of print]

PURPOSE OF THE STUDY: the aim of this study was to synthesize PFC fNIRS outcomes on the effects of cognitive tasks compared to resting/baseline tasks in healthy adults from studies utilizing a pre/post design. MATERIAL AND METHODS: original research studies were searched from seven databases (MEDLINE, EMBASE, CENTRAL, CINAHL, SCOPUS, PEDro and PubMed). Subsequently, two independent reviewers screened the titles and abstracts followed by full-text reviews to assess the studies' eligibility. RESULTS: eleven studies met the inclusion criteria and had data abstracted and quality assessed. Methodology varied considerably and yet cognitive tasks resulted in the ?O2Hb increasing in 8 of the 11 and ?HHb decreasing in 8 of 8 studies that reported this outcome. The cognitive tasks from 10 of the 11 studies were classified as "Working Memory" and "Verbal Fluency Tasks". CONCLUSIONS: although, the data comparison was challenging provided the heterogeneity in methodology, the results across studies were similar.

Forgiveness and cognitive control - Provoking revenge via theta-burst-stimulation of the DLPFC.

Maier MJ, Rosenbaum D, Haeussinger FB, Brne M, Enzi B, Plewnia C, Fallgatter AJ, Ehlis AC.

Neuroimage. Dec;183:769-
doi: 10.1016/j.neuroimage.2018.08.Epub Aug 28.

In order to act in a socially acceptable way, the ability to forgive is indispensable. It has been suggested that forgiveness relies on cognitive control, more specifically inhibition. In this study, we combined an ultimatum game (UG) and a dictator game (DG) with inhibitory, continuous theta-burst stimulation (cTBS; verum vs. placebo, within-subjects design) of the right dorsolateral prefrontal cortex (DLPFC) to investigate the effect of reduced cognitive control on forgiveness. To this end, participants played an UG against fair and unfair opponents, where they had to accept or reject (fair and unfair) monetary offers, and then received a cTBS prior to playing a DG against the same opponents with reversed roles. The participants now had the possibility to forgive the unfair opponents (allocation of a fair amount of money) or to take revenge whereby the cTBS effects were assessed with functional near-infrared spectroscopy. Following verum cTBS, participants allocated significantly less money to their unfair opponents than in the placebo cTBS condition. Also, reaction times (RTs)

differed significantly between verum and placebo cTBS for unfair opponents (higher RTs following verum stimulation) but not for fair opponents. These results strongly indicate that cognitive control is a fundamental requirement for overcoming unwanted emotional responses.

Correction: fNIRS measurement of cortical activation and functional connectivity during a visuospatial working memory task.

Baker JM, Bruno JL, Gundran A, Hosseini SMH, Reiss AL.

PLoS One. Aug 24;13(8):e

doi: 10.1371/journal.pone.0203233. eCollection 2018.

[This corrects the article DOI: 10.1371/journal.pone.0201486.].

Whole-cortical graphical networks at wakeful rest in young and older adults revealed by functional near-infrared spectroscopy.

Li L, Babawale O, Yennu A, Trowbridge C, Hulla R, Gatchel RJ, Liu H.

Neurophotonics. Jul;5(3):

doi: 10.1117/1.NPh.5.3.Epub 2018 Jul 27.

A good understanding of age-dependent changes and modifications in brain networks is crucial for fully exploring the effects of aging on the human brain. Few reports have been found in studies of functional brain networks using functional near-infrared spectroscopy (fNIRS). Moreover, little is known about the feasibility of using fNIRS to assess age-related changes in brain connectomes. This study applied whole brain fNIRS measurement, combined with graph theory analysis, to assess the age-dependent changes in resting-state brain networks. Five to eight minutes of resting-state brain hemodynamic signals were recorded from 48 participants (18 young adults and 30 older adults) with 133 optical channels covering the majority of the cortical regions. Both local and global graph metrics were computed to identify the age-related changes of topographical brain networks. Older adults showed an overall decline of both global and local efficiency compared to young adults, as well as the decline of small-worldness. In addition, young adults showed the abundance of hubs in the prefrontal cortex, whereas older adults revealed the hub shifts to the sensorimotor cortex. These obvious shifts of hubs may potentially indicate decreases of the decision-making,

memory, and other high-order functions as people age. Our results showed consistent findings with published literature and also demonstrated the feasibility of whole-head fNIRS measurements to assess age-dependent changes in resting-state brain networks.

A cross-brain neural mechanism for human-to-human verbal communication.

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

Soc Cogn Affect Neurosci. Sep 11;13(9):907-

doi: 10.1093/scan/nsy070.

Neural mechanisms that mediate dynamic social interactions remain understudied despite their evolutionary significance. The interactive brain hypothesis proposes that interactive social cues are processed by dedicated brain substrates and provides a general theoretical framework for investigating the underlying neural mechanisms of social interaction. We test the specific case of this hypothesis proposing that canonical language areas are upregulated and dynamically coupled across brains during social interactions based on talking and listening. Functional near-infrared spectroscopy (fNIRS) was employed to acquire simultaneous deoxyhemoglobin (deOxyHb) signals of the brain on partners who alternated between speaking and listening while doing an Object Naming & Description task with and without interaction in a natural setting. Comparison of interactive and non-interactive conditions confirmed an increase in neural activity associated with Wernicke's area including the superior temporal gyrus (STG) during interaction (P=0.04). However, the hypothesis was not supported for Broca's area. Cross-brain coherence determined by wavelet analyses of signals originating from the STG and the subcentral area was greater during interaction than non-interaction (P<0.01). In support of the interactive brain hypothesis these findings suggest a dynamically coupled cross-brain neural mechanism dedicated to pathways that share interpersonal information.

A Functional Near-Infrared Spectroscopy Study of State Anxiety and Auditory Working Memory Load.

Tseng YL, Lu CF, Wu SM, Shimada S, Huang T, Lu GY.

Front Hum Neurosci. Aug 7;12:

doi: 10.3389/fnhum.2018.eCollection 2018.

Cognitive studies have suggested that anxiety is correlated with cognitive performance. Previous research has focused on the relationship between anxiety level and the perceptual load within the frontal region, such as the dorsolateral prefrontal and anterior cingulate cortices. High-anxious individuals are predicted to have worse performance on cognitively-demanding tasks requiring efficient cognitive processing. A few functional magnetic resonance imaging studies have specifically discussed the performance and brain activity involving working memory for high-anxious individuals. This topic has been further explored with electroencephalography, although these studies have mostly provided results involving visual face-related stimuli. In this study, we used auditory stimulation to manipulate the working memory load and attempted to interpret the deficiency of cognitive function in high-anxious participants or patients using functional near infrared spectroscopy (fNIRS). The fNIRS signals of 30 participants were measured while they were performing an auditory working memory task. For the auditory n-back task, there were three experimental conditions, including two n-back task conditions of stimuli memorization with different memory load and a condition of passive listening to the stimuli. Hemodynamic responses from frontal brain regions were recorded using a wireless fNIRS device. Brain activation from the ventrolateral and orbital prefrontal cortex were measured with signals filtered and artifacts removed. The fNIRS signals were then standardized with statistical testing and group analysis was performed. The results revealed that there were significantly stronger hemodynamic responses in the right ventrolateral and orbital prefrontal cortex when subjects were attending to the auditory working memory task with higher load. Furthermore, the right lateralization of the prefrontal cortex was negatively correlated with the level of state anxiety. This study revealed the possibility of incorporating fNIRS signals as an index to evaluate cognitive performance and mood states given its flexibility regarding portable applications compared to other neuroimaging techniques.

Attenuation of long-range temporal correlations of neuronal oscillations in young children with autism spectrum disorder.

Jia H, Li Y, Yu D.

Neuroimage Clin. Aug 9;20:424-
doi: 10.1016/j.nicl.2018.08.012. eCollection 2018.

Although autism spectrum disorder (ASD) was previously found to be

associated with aberrant brain structure, neuronal amplitudes and spatial neuronal interactions, surprisingly little is known about the temporal dynamics of neuronal oscillations in this disease. Here, the hemoglobin concentration signals (i.e., oxy-Hb and deoxy-Hb) of young children with ASD and typically developing (TD) children were recorded via functional near infrared spectroscopy (fNIRS) when they were watching a cartoon. The long-range temporal correlations (LRTCs) of hemoglobin concentration signals were quantified using detrended fluctuation analysis (DFA). Compared with TD group, the DFA exponents of young children with ASD were significantly smaller over left temporal region for oxy-Hb signal, and over bilateral temporo-occipital regions for deoxy-Hb signals, indicating a shift-to-randomness of brain oscillations in the children with ASD. Testing the relationship between age and DFA exponents revealed that this association could be modulated by autism. The correlation coefficients between age and DFA exponents were significantly more positive in TD group, compared to those in ASD group over several brain regions. Furthermore, the DFA exponents of oxy-Hb in left temporal region were negatively correlated with autistic symptom severity. These results suggest that the decreased DFA exponent of hemoglobin concentration signals may be one of the pathologic changes in ASD, and studying the temporal structure of brain activity via fNIRS technique may provide physiological indicators for autism.

Hand or spoon? Exploring the neural basis of affective touch in 5-month-old infants.

Pirazzoli L, Lloyd-Fox S, Braukmann R, Johnson MH, Gliga T.

Dev Cogn Neurosci. Feb;35:28-
doi: 10.1016/j.dcn.2018.06.Epub 2018 Jul 5.

In adults, affective touch leads to widespread activation of cortical areas including posterior Superior Temporal Sulcus (pSTS) and Inferior Frontal Gyrus (IFG). Using functional Near Infrared Spectroscopy (fNIRS), we asked whether similar areas are activated in 5-month-old infants, by comparing affective to non-affective touch. We contrasted a human touch stroke to strokes performed with a cold metallic spoon. The hypothesis that adult-like activation of cortical areas would be seen only in response to the human touch stroke was not confirmed. Similar patterns of activation were seen in both conditions. We conclude that either the posterior STS and IFG have not yet developed selective responses to affective touch, or that additional social cues are needed to be able to identify this type of touch.

Distinct fNIRS-derived HbO2 trajectories during the course and over repeated walking trials under single and dual-task conditions: implications for within session learning and prefrontal cortex efficiency in older adults.

Holtzer R, Izzetoglu M, Chen M, Wang C.

J Gerontol A Biol Sci Med Sci. Aug
doi: 10.1093/gerona/gly[Epub ahead of print]

Background: Neural trajectories of gait are not well established. We determined two distinct, clinically relevant neural trajectories, operationalized via functional-Near-Infrared-Spectroscopy (fNIRS) HbO2 measures in the prefrontal cortex (PFC), under single-task-walk (STW) and dual-task-walk (DTW) conditions. Course trajectory assessed neural activity associated with attention during the course of a walking task; the second trajectory assessed neural activity associated with learning over repeated walking trials. Improved neural efficiency was defined as reduced PFC HbO2 after practice. Methods: Walking was assessed under STW and DTW conditions. fNIRS was utilized to quantify HbO2 in the PFC while walking. Burst measurement included three repeated trials for each experimental condition. The course of each walking task consisted of six consecutive segments. Results: 83 non-demented participants (mean age=78.056.37ys; %female=49.5) were included. Stride velocity (estimate=-0.5259cm/sec, p=<0.0001) and the rate of correct letter generation (log estimate of rate ratio=-0.0377, p<0.0001) declined during the course of DTW. In contrast, stride velocity (estimate=1.4577 cm/sec, p<0.0001) and the rate of correct letter generation (log estimate of rate ratio=0.0578, p<0.0001) improved over repeated DTW trials. Course and trial effects were not significant in STW. HbO2 increased during the course of DTW (estimate=0.0454M, p<0.0001) but declined over repeated trials (estimate=-0.1786M, p<0.0001). HbO2 declined during the course of STW (estimate=-0.0542M, p<0.0001) but didn't change significantly over repeated trials. Conclusion: We provided evidence for distinct attention (course) and learning (repeated trials) trajectories and their corresponding PFC activity. Findings suggest that learning and improved PFC efficiency were demonstrated in one experimental session involving repeated DTW trials.

Optimal positioning of optodes on the scalp for personalized

functional near-infrared spectroscopy investigations.

Machado A, Cai Z, Pellegrino G, Marcotte O, Vincent T, Lina JM, Kobayashi E, Grova C.

J Neurosci Methods. Nov 1;309:91-
doi: 10.1016/j.jneumeth.2018.08.006. Epub Aug 11.

BACKGROUND: Application of functional Near InfraRed Spectroscopy (fNIRS) in neurology is still limited as a good optical coupling and optimized optode coverage of specific brain regions remains challenging, notably for prolonged monitoring. METHODS: We propose to evaluate a new procedure allowing accurate investigation of specific brain regions. The procedure consists in: (i) A priori maximization of spatial sensitivity of fNIRS measurements targeting specific brain regions, while reducing the number of applied optodes in order to decrease installation time and improve subject comfort. (ii) Utilization of a 3D neuronavigation device and usage of collodion to glue optodes on the scalp, ensuring good optical contact for prolonged investigations. (iii) Local reconstruction of the hemodynamic activity along the cortical surface using inverse modelling. RESULTS: Using realistic simulations, we demonstrated that maps derived from optimal montage acquisitions showed, after reconstruction, spatial resolution only slightly lower to that of ultra high density montages while significantly reducing the number of optodes. The optimal montages provided overall good quantitative accuracy especially at the peak of the spatially reconstructed map. We also evaluated real motor responses in two healthy subjects and obtained reproducible motor responses over different sessions. COMPARISON WITH EXISTING METHODS: We are among the first to propose a mathematical optimization strategy, allowing high sensitivity measurements. CONCLUSIONS: Our results support that using personalized optimal montages should allow to conduct accurate fNIRS studies in clinical settings and realistic lifestyle conditions.

Prefrontal Cortex Oxygenation Evoked by Convergence Load Under Conflicting Stimulus-to-Accommodation and Stimulus-to-Vergence Eye-Movements Measured by NIRS.

Richter HO, Forsman M, Elcadi GH, Brautaset R, Marsh JE, Zetterberg C.

Front Hum Neurosci. Jul 30;12:
doi: 10.3389/fnhum.2018.00298. eCollection 2018.

Erratum in Front Hum Neurosci. 2018 Sep 19;12:384.

Functional Near-Infrared Spectroscopy Recordings of Visuospatial Working Memory Processes. Part II: A Replication Study in Children on Sensitivity and Mental-Ability-Induced Differences in Functional Activation.

Witmer JS, Aeschlimann EA, Metz AJ, Troche SJ, Rammsayer TH.

Brain Sci. Aug 12;8(8). pii: E
doi: 10.3390/brainsci8080152.

In a previous study in young adults, we showed that hemodynamic changes as measured by functional near-infrared spectroscopy (fNIRS) were sensitive for identifying visuospatial working memory (WM)-related functional brain activation in the prefrontal cortex. This functional activation, however, could not be verified for participants with far-above-average mental ability, suggesting different cognitive processes adopted by this group. The present study was designed to confirm these findings in 11- to 13-year-old children by applying the same study design, experimental task, fNIRS setup, and statistical approach. We successfully replicated the earlier findings on sensitivity of fNIRS with regard to visuospatial WM-specific task demands in our children sample. Likewise, mental-ability-induced differences in functional activation were even more pronounced in the children compared with in the young adults. By testing a children sample, we were able to not only replicate our previous findings based on adult participants but also generalize the validity of these findings to children. This latter aspect seems to be of particular significance considering the relatively large number of fNIRS studies on WM performance in children.

Relationship between sensorimotor cortical activation as assessed by functional near infrared spectroscopy and lower extremity motor coordination in bilateral cerebral palsy.

Sukal-Moulton T, de Campos AC, Alter KE, Huppert TJ, Damiano DL.

Neuroimage Clin. Jul 30;20:275-
doi: 10.1016/j.nicl.2018.07.023. eCollection 2018.

Background: Evaluation of task-evoked cortical responses during movement has been limited in individuals with bilateral cerebral palsy (CP), despite documented alterations in brain structure/function and deficits in motor control. Objective: To systematically evaluate cortical activity associated with lower extremity tasks, and relate activation parameters to

clinical measures in CP. Methods: 28 ambulatory participants (14 with bilateral CP and 14 with typical development) completed five motor tasks (non-dominant ankle dorsiflexion, hip flexion and leg cycling as well as bilateral dorsiflexion and cycling) in a block design while their sensorimotor cortex was monitored using functional near infrared spectroscopy (fNIRS), in addition to laboratory and clinical measures of performance. Results: Main effects for group and task were found for extent of fNIRS activation (number of active channels; $p < 0.001$ and $p = 0.010$, respectively), magnitude of activation (sum of beta values; $p < 0.001$ for both), and number of active muscles ($p = 0.001$ and $p < 0.001$, respectively), but no group by task interactions. Collectively, subgroups with CP and especially those with greater impairments, showed higher extent and magnitude of cortical sensorimotor activation as well as higher amounts of concurrent activity in muscles not required for task performance. Magnitude of fNIRS activation during non-dominant dorsiflexion correlated with validated measures of selective control ($r = -0.60$, $p = 0.03$), as well as mobility and daily activity ($r = -0.55$, $p = 0.04$ and $r = -0.52$, $p = 0.05$, respectively) and self-reported gait function ($r = -0.68$, $p = 0.01$) in those with CP. Conclusions: The association between higher activity in the sensorimotor cortex and decreased selectivity in cortical organization suggests a potential neural mechanism of motor deficits and target for intervention.

The origins of cortical multisensory dynamics: Evidence from human infants.

Werchan DM, Baumgartner HA, Lewkowicz DJ, Amso D.

Dev Cogn Neurosci. Nov;34:75-

doi: 10.1016/j.dcn.2018.07.Epub 2018 Aug 3.

Erratum in Dev Cogn Neurosci. 2018 Dec 18;:.

Mental workload is reflected in driver behaviour, physiology, eye movements and prefrontal cortex activation.

Foy HJ, Chapman P.

Appl Ergon. Nov;73:90-

doi: 10.1016/j.apergo.2018.06.Epub Jun 26.

Mental workload is an important factor during driving, as both high and low levels may result in driver error. This research examined the men-

tal workload of drivers caused by changes in road environment and how such changes impact upon behaviour, physiological responses, eye movements and brain activity. The experiment used functional near infrared spectroscopy to record prefrontal cortex activation associated with changes in mental workload during simulated driving. Increases in subjective ratings of mental workload caused by changes in road type were accompanied by increases in skin conductance, acceleration signatures and horizontal spread of search. Such changes were also associated with increases in the concentration of oxygenated haemoglobin in the prefrontal cortex. Mental workload fluctuates during driving. Such changes can be identified using a range of measures which could be used to inform the development of in-vehicle devices and partially autonomous systems.

Imagine squeezing a cactus: Cortical activation during affective motor imagery measured by functional near-infrared spectroscopy.

Wriessnegger SC, Bauernfeind G, Kurz EM, Raggam P, Mller-Putz GR.

Brain Cogn. Oct;126:13-
doi: 10.1016/j.bandc.2018.07.Epub Aug 7.

The activation of different brain areas during kinaesthetic and visual motor imagery has been extensively studied, whereas little is known about affective motor imagery, i.e. the imagery of pleasant/unpleasant movements. In the present neuroimaging study we investigated cortical activation of kinaesthetic motor imagery (KMI) based on emotional stimulus content by means of functional near infrared spectroscopy (fNIRS). Twenty healthy adult participants were instructed to imagine affective, and neutral motor tasks while multichannel fNIRS was recorded simultaneously. In the affective MI condition they had to imagine e.g. squeezing a cactus with their right hand several times, eliciting an unpleasant emotion. In the neutral condition their task was to imagine squeezing a ball. Significant differences in oxyhemoglobin [oxy-Hb] concentration changes during KMI including affective objects in different brain regions were found. Specifically activation in left parietal and frontal regions was increased during the imagery of squeezing a cactus which induced a painful feeling. Both areas are also involved in the perception of pain and commonly labelled as parts of the "pain matrix". Our study provides novel insights in cortical activation patterns during affective motor imagery and its psychological and cognitive mechanisms underlying pain experience.

Functional near-infrared spectroscopy for monitoring macaque cerebral motor activity during voluntary movements without head fixation.

Yamada T, Kawaguchi H, Kato J, Matsuda K, Higo N.

Sci Rep. Aug 9;8(1):
doi: 10.1038/s41598-018-30416-7.

We developed an fNIRS system for monitoring macaque cerebral motor activity during voluntary movements without head fixation. fNIRS data at 27 channels in 7.5?mm spatial interval were calibrated by simulating light propagation through the macaque cranial tissues. The subject was instructed to repeatedly (75 times) retrieve a food pellet with alternating left or right hands from a food well for each session. We detected significant increases in oxygenated hemoglobin (Hb) and decrease in deoxygenated Hb in the primary motor area (M1) contralateral to the hand used. In more rostral and ventral regions in both hemispheres, the hemodynamic similarly changed regardless of used hand. Direct feeding to the mouth eliminated activity in the hand M1 whereas that at bilateral ventral regions (mouth M1 area) remained. Statistical analyses for the hemodynamics between left/right-hand use revealed the location of each hand M1 in either hemisphere. In these regions, the maximum amplitude and time of the maximum amplitude in the hemodynamic response evoked by food retrieval were highly correlated with the time associated with food retrieval. We could assign each channel to an appropriate functional motor area, providing proof of principle for future studies involving brain damage models in freely moving macaque monkeys.

Interpersonal synchronization of inferior frontal cortices tracks social interactive learning of a song.

Pan Y, Novembre G, Song B, Li X, Hu Y.

Neuroimage. Dec;183:280-
doi: 10.1016/j.neuroimage.2018.08.Epub Aug 4.

Much of human learning emerges as a result of interaction with others. Yet, this interpersonal process has been poorly characterized from a neurophysiological perspective. This study investigated (i) whether Interpersonal Brain Synchronization (IBS) can reliably mark social interactive learning, and specifically (ii) during what kind of interactive behavior. We recorded

brain activity from learner-instructor dyads using functional Near-Infrared Spectroscopy (fNIRS) during the acquisition of a music song. We made four fundamental observations. First, during the interactive learning task, brain activity recorded from the bilateral Inferior Frontal Cortex (IFC) synchronized across the learner and the instructor. Second, such IBS was observed in particular when the learner was observing the instructor's vocal behavior and when the learning experience entailed a turn-taking and more active mode of interaction. Third, this specific enhancement of IBS predicted learner's behavioral performance. Fourth, Granger causality analyses further disclosed that the signal recorded from the instructor's brain better predicted that recorded from the learner's brain than vice versa. Together, these results indicate that social interactive learning can be neurophysiologically characterized in terms of IBS. Furthermore, they suggest that the learner's involvement in the learning experience, alongside the instructor's modeling, are key factors driving the alignment of neural processes across learner and instructor. Such alignment impacts upon the real-time acquisition of new information and eventually upon the learning (behavioral) performance. Hence, besides providing a biological characterization of social interactive learning, our results hold relevance for clinical and pedagogical practices.

The present and future use of functional near-infrared spectroscopy (fNIRS) for cognitive neuroscience.

Pinti P, Tachtsidis I, Hamilton A, Hirsch J, Aichelburg C, Gilbert S, Burgess PW.

Ann N Y Acad Sci. Aug
doi: 10.1111/nyas.[Epub ahead of print]

The past few decades have seen a rapid increase in the use of functional near-infrared spectroscopy (fNIRS) in cognitive neuroscience. This fast growth is due to the several advances that fNIRS offers over the other neuroimaging modalities such as functional magnetic resonance imaging and electroencephalography/magnetoencephalography. In particular, fNIRS is harmless, tolerant to bodily movements, and highly portable, being suitable for all possible participant populations, from newborns to the elderly and experimental settings, both inside and outside the laboratory. In this review we aim to provide a comprehensive and state-of-the-art review of fNIRS basics, technical developments, and applications. In particular, we discuss some of the open challenges and the potential of fNIRS for cognitive neu-

roscience research, with a particular focus on neuroimaging in naturalistic environments and social cognitive neuroscience.

Measuring visual cortical oxygenation in diabetes using functional near-infrared spectroscopy.

Aitchison RT, Ward L, Kennedy GJ, Shu X, Mansfield DC, Shahani U.

Acta Diabetol. Nov;55(11):1181-
doi: 10.1007/s00592-018-1200-Epub Aug 6.

AIMS: Diabetes mellitus affects about 6% of the world's population, and the chronic complications of the disease may result in macro- and microvascular changes. The purpose of the current study was to shed light on visual cortical oxygenation in diabetic individuals. We then aimed to compare the haemodynamic response (HDR) to visual stimulation with glycaemic control, given the likelihood of diabetic individuals suffering from such macro- and micro-vascular insult. METHODOLOGY: Thirty participants took part in this explorative study, fifteen of whom had diabetes and fifteen of whom were non-diabetic controls. The HDR, measured as concentrations of oxyhaemoglobin [HbO] and deoxyhaemoglobin [HbR], to visual stimulation was recorded over the primary visual cortex (V1) using a dual-channel oximeter. The stimulus comprised a pattern-reversal checkerboard presented in a block design. Participants' mean glycated haemoglobin (HbA1c) level (?SD) was 7.2??0.6% in the diabetic group and 5.5??0.4% in the non-diabetic group. Raw haemodynamic data were normalised to baseline, and the last 15s of data from each 'stimulus on' and 'stimulus off' condition were averaged over seven duty cycles for each participant. RESULTS: There were statistically significant differences in ?[HbO] and ?[HbR] to visual stimulation between diabetic and non-diabetic groups (p?<?0.05). In the diabetic group, individuals with type 1 diabetes displayed an increased [HbO] (p?<?0.01) and decreased [HbR] (p?<?0.05) compared to their type 2 counterparts. There was also a linear relationship between both ?[HbO] and ?[HbR] as a function of HbA1c level (p?<?0.0005). CONCLUSIONS: Our findings suggest that fNIRS can be used as a quantitative measure of cortical oxygenation in diabetes. Diabetic individuals have a larger HDR to visual stimulation compared to non-diabetic individuals. This increase in ?[HbO] and decrease in ?[HbR] appears to be correlated with HbA1c level.

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fNIRS measurement of cortical activation and functional connectivity during a visuospatial working memory task.

Baker JM, Bruno JL, Gundran A, Hosseini SMH, Reiss AL.

PLoS One. Aug 2;13(8):e
doi: 10.1371/journal.pone.0201486. eCollection 2018.
Erratum in PLoS One. 2018 Aug 24;13(8):e0203233.

The Influence of Medical Professional Knowledge on Empathy for Pain: Evidence From fNIRS.

Xie J, Yang H, Xia X, Yu S.

Front Psychol. Jul 17;9:
doi: 10.3389/fpsyg.2018.eCollection 2018.

Empathy is a mental ability that allows one person to understand the mental and emotional state of another and determines how to effectively respond to that person. When a person receives cues that another person is in pain, neural pain circuits within the brain are activated. Studies have shown that compared with non-medical staff, medical practitioners present lower empathy for pain in medical scenarios, but the mechanism of this phenomenon remains in dispute. This work investigates whether the neural correlates of empathic processes of pain are altered by professional medical knowledge. The participants were 16 medical students who were enrolled at a Chinese medical college and 16 non-medical students who were enrolled at a normal university. Participants were scanned by functional near-infrared spectroscopy while watching pictures of medical scenarios that were either painful or neutral situations. Subjects were asked to evaluate the pain intensity supposedly felt by the model in the stimulus displays, and the Interpersonal Reactivity Index-C (IRI-C) questionnaire was used to measure the empathic ability of participants. The results showed that there is no significant difference between medical professional and non-medical professional subjects in IRI-C questionnaire scores. The subjects of medical professions rated the pain degree of medical pictures significantly lower than those of non-medical professions. The activation areas in non-medical subjects were mainly located in the dorsolateral prefrontal cortex, frontal polar regions, posterior part of the inferior frontal gyrus, supramarginal gyrus, supplementary somatosensory cortex and angular gyrus, whereas there was a wide range of activation in the prefrontal lobe region in addition to the somatosensory cortex in medical professionals. These results indicate that the process of pain empathy in medical settings is influenced by medical professional

knowledge.

Putting our heads together: interpersonal neural synchronization as a biological mechanism for shared intentionality.

Fishburn FA, Murty VP, Hlutkowsky CO, MacGillivray CE, Bemis LM, Murphy ME, Huppert TJ, Perlman SB.

Soc Cogn Affect Neurosci. Sep 5;13(8):841-
doi: 10.1093/scan/nsy060.

Shared intentionality, or collaborative interactions in which individuals have a shared goal and must coordinate their efforts, is a core component of human interaction. However, the biological bases of shared intentionality and, specifically, the processes by which the brain adjusts to the sharing of common goals, remain largely unknown. Using functional near infrared spectroscopy (fNIRS), coordination of cerebral hemodynamic activation was found in subject pairs when completing a puzzle together in contrast to a condition in which subjects completed identical but individual puzzles (same intention without shared intentionality). Interpersonal neural coordination was also greater when completing a puzzle together compared to two control conditions including the observation of another pair completing the same puzzle task or watching a movie with a partner (shared experience). Further, permutation testing revealed that the time course of neural activation of one subject predicted that of their partner, but not that of others completing the identical puzzle in different partner sets. Results indicate unique brain-to-brain coupling specific to shared intentionality beyond what has been previously found by investigating the fundamentals of social exchange.

Neuroticism and conscientiousness respectively positively and negatively correlated with the network characteristic path length in dorsal lateral prefrontal cortex: A resting-state fNIRS study.

Wang MY, Zhang J, Lu FM, Xiang YT, Yuan Z.

Brain Behav. Sep;8(9):e
doi: 10.1002/brb3.Epub Jul 27.

BACKGROUND: Accumulating evidence shows that the dorsal lateral prefrontal cortex (dlPFC) is implicated in personality traits. In this study, resting-state functional near infrared spectroscopy (fNIRS) combined with

small-world analysis was utilized to examine the relationship between the network properties of dlPFC and personality traits. METHODS: Thirty college students (aged between 20 and 29) were recruited from the University of Macau campus, whose personality scores were accessed with the NEO-FFT questionnaire. Graph theory combined with resting-state fNIRS data was used to quantify the network properties of dlPFC, whereas Pearson correlation analysis was performed to generate the relationship between the small-world indicators and personality scores. RESULTS: Compared to matched random networks, the resting-state brain networks exhibited a larger clustering coefficient (Cp , 0.1-0.66), shorter characteristic path length (Lp , 0.1-0.66), and higher global (Eg , 0.1-0.66) and local efficiency (Eloc , 0.1-0.65). In particular, conscientiousness (r=-0.63) and neuroticism (r=0.40) respectively showed negative and positive correlation with the Lp . CONCLUSIONS: The resting-state functional brain networks in dlPFC exhibited the small-world properties. In addition, participants with higher conscientiousness scores showed a shorter Lp .

Neuronal Activation Detection Using Vector Phase Analysis with Dual Threshold Circles: A Functional Near-Infrared Spectroscopy Study.

Zafar A, Hong KS.

Int J Neural Syst. Dec;28(10):
doi: 10.1142/SEpub Jun 24.

In this paper, a new vector phase diagram differentiating the initial decreasing phase (i.e. initial dip) and the delayed hemodynamic response (HR) phase of oxy-hemoglobin changes (? HbO) of functional near-infrared spectroscopy (fNIRS) is developed. The vector phase diagram displays the trajectories of ? HbO and deoxy-hemoglobin changes (? HbR), as orthogonal components, in the ? HbO- ? HbR polar coordinates. To determine the occurrence of an initial dip, dual threshold circles (an inner circle from the resting state, an outer circle from the peak values of the initial dip and the main HR) are incorporated into the phase diagram for making decisions. The proposed scheme is then applied to a brain-computer interface scheme, and its performance is evaluated in classifying two finger tapping tasks (right-hand thumb and little finger) from the left motor cortex. Three gamma functions are used to model the initial dip, the main HR, and the undershoot in generating the designed HR function. In classifying two tapping tasks, the signal mean and signal minimum values during 0-2.5 s, as

features of initial dip, are used. The linear discriminant analysis was utilized as a classifier. The experimental results show that the active brain locations of the two tasks were quite distinctive ($p < 0.05$), and moreover, spatially specific if using the initial dip map at 4 s in comparison to the map of HRs at 14 s. Also, the average classification accuracy was improved from 59% to 74.9% when using the phase diagram of dual threshold circles.

Concurrent Changes of Brain Functional Connectivity and Motor Variability When Adapting to Task Constraints.

Vergotte G, Perrey S, Muthuraman M, Janaqi S, Torre K.

Front Physiol. Jul 10;9:

doi: 10.3389/fphys.2018.eCollection 2018.

In behavioral neuroscience, the adaptability of humans facing different constraints has been addressed on one side at the brain level, where a variety of functional networks dynamically support the same performance, and on the other side at the behavioral level, where fractal properties in sensorimotor variables have been considered as a hallmark of adaptability. To bridge the gap between the two levels of observation, we have jointly investigated the changes of network connectivity in the sensorimotor cortex assessed by modularity analysis and the properties of motor variability assessed by multifractal analysis during a prolonged tapping task. Four groups of participants had to produce the same tapping performance while being deprived from 0, 1, 2, or 3 sensory feedbacks simultaneously (auditory and/or visual and/or tactile). Whereas tapping performance was not statistically different across groups, the number of brain networks involved and the degree of multifractality of the inter-tap interval series were significantly correlated, increasing as a function of feedback deprivation. Our findings provide first evidence that concomitant changes in brain modularity and multifractal properties characterize adaptations underlying unchanged performance. We discuss implications of our findings with respect to the degeneracy properties of complex systems, and the entanglement of adaptability and effective adaptation.

FNIRS activity in the prefrontal cortex and motivational intensity: impact of working memory load, financial reward, and correlation-based signal improvement.

Fairclough SH, Burns C, Kreplin U.
Neurophotonics. Jul;5(3):
doi: 10.1117/1.NPh.5.3.Epub 2018 Jul 12.

Previous research has demonstrated changes in neurovascular activation of the prefrontal cortex to increased working memory load. The primary purpose of the current paper was to investigate overload of working memory capacity using functional near-infrared spectroscopy (fNIRS) within the framework of motivational intensity theory. A secondary goal was to explore the influence of the correlation-based signal improvement (CBSI) as a method for correcting the influence of systemic variables. In study one, 30 participants (15 female, mean age = 21.09 years, s.d. = 2.9 years) performed a verbal version of the n -back working memory task under four levels of demand (easy, hard, very hard, and impossible). In contrast to the raw data, CBSI-transformed fNIRS data indicated that neurovascular coupling was highest at hard demand when the task was challenging but success was possible. The second study (N=30 ; 15 female, mean age = 22.4 years, s.d. = 5.3) replicated the working memory manipulation with the addition of low versus high levels of financial reward. Analyses of CBSI-transformed levels of oxygenated (HbO) and deoxygenated (HHb) hemoglobin replicated the first study at right lateral regions of the prefrontal cortex (BA46). HHb_CBSI data were significantly reduced at impossible demand for participants receiving the higher level of financial reward. The study is the first to support predictions from the motivational intensity model using neurovascular data. In addition, the application of CBSI to fNIRS data was found to improve the sensitivity of HbO and Hbb to the independent variables.

Towards optimal visual presentation design for hybrid EEG-fTCD brain-computer interfaces.

Khalaf A, Sejdic E, Akcakaya M.
J Neural Eng. Oct;15(5):
doi: 10.1088/1741-2552/aad46f. Epub Jul 19.

DOI: 10.1088/1741-2552/aad46f PMID: 30021931

Concurrent exergaming and transcranial direct current stimulation to improve balance in people with Parkinson's disease: study protocol for a randomised controlled trial.

Harris DM, Rantalainen T, Muthalib M, Johnson L, Duckham RL, Smith ST, Daly RM, Teo WP.
Trials. Jul 16;19(1):
doi: 10.1186/s13063-018-2773-6.

BACKGROUND: People with Parkinson's disease (PD) commonly experience postural instability, resulting in poor balance and an increased risk of falls. Exercise-based video gaming (exergaming) is a form of physical training that is delivered through virtual reality technology to facilitate motor learning and is efficacious in improving balance in aged populations. In addition, studies have shown that anodal transcranial direct current stimulation (a-tDCS), when applied to the primary motor cortex, can augment motor learning when combined with physical training. However, no studies have investigated the combined effects of exergaming and tDCS on balance in people with PD. METHODS/DESIGN: Twenty-four people with mild to moderate PD (Hoehn and Yahr scale score 2-4) will be randomly allocated to receive one of three interventions: (1) exergaming + a-tDCS, (2) exergaming + sham a-tDCS or (3) usual care. Participants in each exergaming group will perform two training sessions per week for 12 weeks. Each exergaming session will consist of a series of static and dynamic balance exercises using a rehabilitation-specific software programme (Jintronix) and 20minutes of either sham or real a-tDCS (2mA) delivered concurrently. Participants allocated to usual care will be asked to maintain their normal daily physical activities. All outcome measures will be assessed at baseline and at 6 weeks (mid-intervention), 12 weeks (post-intervention) and 24 weeks (3-month follow-up) after baseline. The primary outcome measure will be the Limits of Stability Test. Secondary outcomes will include measures of static balance, leg strength, functional capacity, cognitive task-related cortical activation, corticospinal excitability and inhibition, and cognitive inhibition. DISCUSSION: This will be the first trial to target balance in people with PD with combined exergaming and a-tDCS. We hypothesise that improvements in balance, functional and neurophysiological outcome measures, and neurocognitive outcome measures will be greater and longer-lasting following concurrent exergaming and a-tDCS than in those receiving sham tDCS or usual care. TRIAL REGISTRATION: Australian New Zealand Clinical Trials Registry, ACTRN12616000594426). Registered on 9 May 2016.

Detecting Concealed Information with Fused Electroencephalography and Functional Near-infrared Spectroscopy.

Lin X, Sai L, Yuan Z.
Neuroscience. Aug 21;386:284-
doi: 10.1016/j.neuroscience.2018.06.049. Epub Jul 10.

In this study, fused electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS) techniques were utilized to examine the relationship between the ERP (event-related potential) component P300 and fNIRS hemodynamic signals for high-accuracy deception detection. During the performance of a modified concealed information test (CIT) task, a series of Chinese names were presented, which served as the target, irrelevant, or the probe stimuli for both the guilty and innocent groups. For participants in the guilty group, the probe stimulus was their individual name, whereas for the innocent group, the probe stimulus was one irrelevant name. In particular, data from concurrent fNIRS and ERP recordings were carefully inspected for participants from the two groups. Interestingly, we discovered that for the guilty group, the probe stimulus elicited significantly higher P300 amplitude at parietal site and also evoked significantly stronger oxyhemoglobin (HbO) concentration changes in the bilateral superior frontal gyrus and bilateral middle frontal gyrus than the irrelevant stimuli. However, this is not the case for the innocent group, in which participants exhibited no significant differences in both ERP and fNIRS measures between the probe and irrelevant stimuli. More importantly, our findings also demonstrated that the combined ERP and fNIRS feature was able to differentiate the guilty and innocent groups with enhanced sensitivity, in which AUC (the area under Receiver Operating Characteristic curve) is 0.94 for deception detection based on the combined indicator, much higher than that based on the ERP component P300 only (0.85) or HbO measure only (0.84).

Neurophysiological correlates of the attention training technique: A component study.
Rosenbaum D, Maier MJ, Hudak J, Metzger FG, Wells A, Fallgatter AJ, Ehlis AC.
Neuroimage Clin. Jun 18;19:1018-
doi: 10.1016/j.nicl.2018.06.021. eCollection 2018.

In the current study, we investigate the neuronal correlates of the Attention Training Technique (ATT), a psychotherapeutic intervention used in metacognitive therapy to enhance flexible cognitive control and ameliorate rumination. We adapted the ATT in a neuroscientific attention paradigm

in order to investigate the effects of its components: selective attention, attention switching and divided attention in comparison to a control task. Functional near-infrared spectroscopy was used to measure changes in blood oxygenation of fronto-lateral and parietal cortical areas. Furthermore, subjects rated their task performance, effort and attention drifts in each task condition. We observed increased blood oxygenation in the right inferior frontal gyrus, right dorsolateral prefrontal cortex and superior parietal lobule during the ATT conditions in comparison to the control condition. Additionally, subjective effort was associated with blood oxygenation in the right inferior prefrontal cortex. Our results are consistent with the theoretical underpinnings of the ATT suggesting that the ATT's mechanism of change lies in the training of areas of the cognitive control network and dorsal attention network. Aberrant functioning of both networks has been shown to be related to depression and rumination.

Feature Extraction and Classification Methods for Hybrid fNIRS-EEG Brain-Computer Interfaces.

Hong KS, Khan MJ, Hong MJ.

Front Hum Neurosci. Jun 28;12:
doi: 10.3389/fnhum.2018.00246. eCollection 2018.

In this study, a brain-computer interface (BCI) framework for hybrid functional near-infrared spectroscopy (fNIRS) and electroencephalography (EEG) for locked-in syndrome (LIS) patients is investigated. Brain tasks, channel selection methods, and feature extraction and classification algorithms available in the literature are reviewed. First, we categorize various types of patients with cognitive and motor impairments to assess the suitability of BCI for each of them. The prefrontal cortex is identified as a suitable brain region for imaging. Second, the brain activity that contributes to the generation of hemodynamic signals is reviewed. Mental arithmetic and word formation tasks are found to be suitable for use with LIS patients. Third, since a specific targeted brain region is needed for BCI, methods for determining the region of interest are reviewed. The combination of a bundled-optode configuration and threshold-integrated vector phase analysis turns out to be a promising solution. Fourth, the usable fNIRS features and EEG features are reviewed. For hybrid BCI, a combination of the signal peak and mean fNIRS signals and the highest band powers of EEG signals is promising. For classification, linear discriminant analysis has been most widely used. However, further research on vector phase analysis as a

classifier for multiple commands is desirable. Overall, proper brain region identification and proper selection of features will improve classification accuracy. In conclusion, five future research issues are identified, and a new BCI scheme, including brain therapy for LIS patients and using the framework of hybrid fNIRS-EEG BCI, is provided.

Binary Classification Using Neural and Clinical Features: An Application in Fibromyalgia with Likelihood based Decision Level Fusion.

Gokcay D, Eken A, Baltaci S.

IEEE J Biomed Health Inform. Jun

doi: 10.1109/JBHI.2018.[Epub ahead of print]

DOI: 10.1109/JBHI.2018.2844300 PMID: 29994341

Single-Trial Classification of fNIRS Signals in Four Directions Motor Imagery Tasks Measured From Prefrontal Cortex.

Peng H, Chao J, Wang S, Dang J, Jiang F, Hu B, Majoe D.

IEEE Trans Nanobioscience. Jul;17(3):181-

doi: 10.1109/TNB.2018.2839736. Epub May 23.

DOI: 10.1109/TNB.2018.2839736 PMID: 29994315

Intersession Instability in fNIRS-Based Emotion Recognition.

Wang F, Mao M, Duan L, Huang Y, Li Z, Zhu C.

IEEE Trans Neural Syst Rehabil Eng. Jul;26(7):1324-

doi: 10.1109/TNSRE.2018.2842464.

DOI: 10.1109/TNSRE.2018.2842464 PMID: 29985142

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

Mazzoni A, Grove R, Eapen V, Lenroot RK, Bruggemann J.

Soc Neurosci. Jul 21:1-

doi: 10.1080/17470919.2018.[Epub ahead of print]

Functional near-infrared spectroscopy (fNIRS) is a neuroimaging technique that has been gaining increasing interest as a method to investigate the brain function of individuals on the autism spectrum. It is a non-invasive, portable and relatively motion-tolerant method of measuring haemodynamic activity in the brain. fNIRS can be particularly effective for quantifying brain function in challenging clinical populations. In light of this, there is a growing body of fNIRS literature focusing on individuals on the autism spectrum. The aim of this review is to evaluate and summarise key studies from the literature and discuss their implications for the field. Potential limitations of the fNIRS approach and resolution of these issues based on emerging fNIRS research are also discussed.

Longtime driving induced cerebral hemodynamic elevation and behavior degradation as assessed by functional near-infrared spectroscopy and a voluntary attention test.

Li T, Lin Y, Gao Y, Zhong F.

J Biophotonics. Dec;11(12):e
doi: 10.1002/jbio.Epub Aug 3.

Drowsy driving contributes to 20% of all traffic accidents worldwide. Onsite monitoring the mental condition of a driver and forewarning may be a preventive solution to reduce occurrence of drowsiness and potential accidents. Functional near-infrared spectroscopy (fNIRS) has been successfully utilized in hemodynamics-interpreted functional activity in preliminary voluntary attention experiments. Here, we monitored hemodynamic alternations using fNIRS upon the prefrontal cortex over 13 volunteers in the course of a 7-hour driving simulation and evaluated their reaction capability with a voluntary attention test based on Go/NoGo paradigm. A degradation in attention test score (Accuracy/RT) as well as the elevations in oxy-hemoglobin (?[HbO2]) and total hemoglobin (?[tHb]) were found significantly correlated with driving duration (Accuracy/RT: r =?-0.964, P < 0.001; ?[HbO2]: r = 0.950, P < 0.001; ?[tHb]: r = 0.852, P = 0.007). The hemodynamic parameters are in significant inverse correlations with Accuracy/RT (?[HbO2]: r =?-0.896, p = 0.003; ?[tHb]: r =?-0.844, P = 0.008), indicating the potential to forewarn drivers the attention degradation with onsite fNIRS measurements.

Differential Path-Length Factor's Effect on the Characterization of Brain's Hemodynamic Response Function: A Functional Near-Infrared Study.

Kamran MA, Mannann MMN, Jeong MY.

Front Neuroinform. Jun 20;12:
doi: 10.3389/fninf.2018.eCollection 2018.

Functional near-infrared spectroscopy (fNIRS) has evolved as a neuroimaging modality over the course of the past two decades. The removal of superfluous information accompanying the optical signal, however, remains a challenge. A comprehensive analysis of each step is necessary to ensure the extraction of actual information from measured fNIRS waveforms. A slight change in shape could alter the features required for fNIRS-BCI applications. In the present study, the effect of the differential path-length factor (DPF) values on the characteristics of the hemodynamic response function (HRF) was investigated. Results were compiled for both simulated data sets and healthy human subjects over a range of DPF values from three to eight. Different sets of activation durations and stimuli were used to generate the simulated signals for further analysis. These signals were split into optical densities under a constrained environment utilizing known values of DPF. Later, different values of DPF were used to analyze the variations of actual HRF. The results, as summarized into four categories, suggest that the DPF can change the main and post-stimuli responses in addition to other interferences. Six healthy subjects participated in this study. Their observed optical brain time-series were fed into an iterative optimization problem in order to estimate the best possible fit of HRF and physiological noises present in the measured signals with free parameters. A series of solutions was derived for different values of DPF in order to analyze the variations of HRF. It was observed that DPF change is responsible for HRF creep from actual values as well as changes in HRF characteristics.

Age-Related Changes in Global Motion Coherence: Conflicting Haemodynamic and Perceptual Responses.

Ward LM, Morison G, Simmers AJ, Shahani U.

Sci Rep. Jul 3;8(1):
doi: 10.1038/s41598-018-27803-5.

Our aim was to use both behavioural and neuroimaging data to identify indicators of perceptual decline in motion processing. We employed a global motion coherence task and functional Near Infrared Spectroscopy (fNIRS).

Healthy adults (n?=?72, 18-85) were recruited into the following groups: young (n?=?28, mean age?=?28), middle-aged (n?=?22, mean age?=?50), and older adults (n?=?23, mean age?=?70). Participants were assessed on their motion coherence thresholds at 3 different speeds using a psychophysical design. As expected, we report age group differences in motion processing as demonstrated by higher motion coherence thresholds in older adults. Crucially, we add correlational data showing that global motion perception declines linearly as a function of age. The associated fNIRS recordings provide a clear physiological correlate of global motion perception. The crux of this study lies in the robust linear correlation between age and haemodynamic response for both measures of oxygenation. We hypothesise that there is an increase in neural recruitment, necessitating an increase in metabolic need and blood flow, which presents as a higher oxygenated haemoglobin response. We report age-related changes in motion perception with poorer behavioural performance (high motion coherence thresholds) associated with an increased haemodynamic response.

Prefrontal modulation during chewing performance in occlusal dysesthesia patients: a functional near-infrared spectroscopy study.

Narita N, Kamiya K, Makiyama Y, Iwaki S, Komiyama O, Ishii T, Wake H.
Clin Oral Investig. Jul
doi: 10.1007/s00784-018-2534-[Epub ahead of print]

OBJECTIVES: Neuropsychological associations can be considerable in occlusal dysesthesia (OD) patients who routinely complain of persistent occlusal discomfort, and somatization effects in the superior medial prefrontal cortex and the temporal and parietal regions are also present. However, the relationship between physical activity, i.e., chewing, prefrontal cognitive demand, and psychiatric states in OD patients remains unclear. We investigated this relationship in this study. MATERIALS AND METHODS: OD patients (n?=?15) and healthy control (n?=?15; HC) subjects were enrolled in this study. Occlusal contact, chewing activities of the masticatory muscles, prefrontal activities, and psychiatric states such as depression and somatization, of the participants were evaluated. Functional near-infrared spectroscopy was used to determine prefrontal hemodynamics and the Symptom Checklist-90-R was used to score the psychiatric states. RESULTS: We observed a significant association between prefrontal deactivation during chewing and somatization subscales in OD patients. Further, there were no

significant differences with regard to the occlusal state and chewing physical activities between the OD patients and HC subjects. CONCLUSIONS: Chewing-related prefrontal deactivation may be associated with somatization severity in OD patients. CLINICAL RELEVANCE: fNIRS is a functional imaging method that uses the principal of neuro-vascular couplings. It is applicable for evaluation of psychiatric state based on prefrontal cortex blood flow in patients with psychiatric disorders.

When Coordinating Finger Tapping to a Variable Beat the Variability Scaling Structure of the Movement and the Cortical BOLD Signal are Both Entrained to the Auditory Stimuli.

Harrison SJ, Hough M, Schmid K, Groff BR, Stergiou N.

Neuroscience. Nov 10;392:203-
doi: 10.1016/j.neuroscience.2018.06.025. Epub Jun 27.

Rhythmic actions are characterizable as a repeating invariant pattern of movement together with variability taking the form of cycle-to-cycle fluctuations. Variability in behavioral measures is atypically random, and often exhibits serial temporal dependencies and statistical self-similarity in the scaling of variability magnitudes across timescales. Self-similar (i.e. fractal) variability scaling is evident in measures of both brain and behavior. Variability scaling structure can be quantified via the scaling exponent (a) from detrended fluctuation analysis (DFA). Here we study the task of coordinating thumb-finger tapping to the beats of constructed auditory stimuli. We test the hypothesis that variability scaling evident in tap-to-tap intervals as well as in the fluctuations of cortical hemodynamics will become entrained to (i.e. drawn toward) manipulated changes in the variability scaling of a stimulus's beat-to-beat intervals. Consistent with this hypothesis, manipulated changes of the exponent a of the experimental stimuli produced corresponding changes in the exponent a of both tap-to-tap intervals and cortical hemodynamics. The changes in hemodynamics were observed in both motor and sensorimotor cortical areas in the contralateral hemisphere. These results were observed only for the longer timescales of the detrended fluctuation analysis used to measure the exponent a. These findings suggest that complex auditory stimuli engage both brain and behavior at the level of variability scaling structures.

Selective Effects of Postural Control on Spatial vs. Nonspatial Working Memory: A Functional Near-Infrared Spectral Imaging Study.

Chen Y, Yu Y, Niu R, Liu Y.

Front Hum Neurosci. Jun 13;12:
doi: 10.3389/fnhum.2018.00243. eCollection 2018.

Background: Previous evidence suggests that postural control processing may be more related to spatial working memory (SWM) than to nonspatial working memory (NWM). Methodological discrepancies between spatial and nonspatial cognitive tasks have made direct comparisons between the two systems difficult. Methods: To explore the neural mechanisms of SWM and NWM relative to that of postural control, participants were subjected a cognitive-posture dual-task paradigm, consisting of a 3-back letter working memory (WM) task, using physically identical stimuli with spatial and nonspatial components memorized in different sessions, and a standing balance task with a tandem stance. Additionally, there were two control sessions: a single-postural control session wherein participants pressed mouse buttons at random while standing; and a single-cognitive task control session wherein subjects completed a WM task while seated. The subjects underwent functional near-infrared spectral imaging (fNIRS) during task performance, wherein oxygenated hemoglobin concentration ([HbO]) was measured in frontal and parietal regions. Results: Postural control reduced discernment in the SWM task significantly, but did not affect NWM task performance. fNIRS showed that postural control had a significant tendency to decrease the [HbO] in the frontal-parietal network of the left hemisphere when participants completed the SWM task. No posture-associated differences in [HbO] were observed in NWM-related areas during NWM task performance. Behavioral and fNIRS data demonstrated that postural control had a selective interaction with SWM. Specifically, postural control reduced SWM discrimination and SWM-related brain activity (frontal-parietal network), but not NWM discrimination or NWM-related brain activity. Furthermore, the multiple linear regression analysis showed that SWM, but not NWM, was an important predictor of postural control. These results suggest that postural control may share more cognitive resources with SWM than with NWM.

Resting-state functional connectivity in prefrontal cortex investigated by functional near-infrared spectroscopy: A longi-

tudinal and cross-sectional study.

Wu S, Gao L, Chen C, Li J, He S.

Neurosci Lett. Sep 14;683:94-
doi: 10.1016/j.neulet.2018.06.Epub Jun 20.

Functional near-infrared spectroscopy (fNIRS) was used to investigate the stability of resting state functional connectivity (RSFC) in the prefrontal cortex. In a longitudinal study for investigating the stability of RSFC with time, we recruited 6 healthy adult subjects to undergo a 10-min resting state fNIRS scan once per day for 7 consecutive days. In a cross-sectional study, 62 healthy subjects underwent a single 10-min RSFC measurement. Three regions-of-interest (ROIs) were studied, the superior frontal gyrus (SFG), the middle frontal gyrus (MFG), and the inferior frontal gyrus (IFG). Homologous RSFC between the left and right hemisphere was computed for each ROI. The longitudinal RSFC study showed no significant variation with time in each ROI, implying that a one-time scan was sufficient for evaluating RSFC for an individual. The cross-sectional study showed significant difference in RSFC between SFG and MFG/IFG. Based on these observations, a lower bound of RSFC with an 85% confidence level for healthy adults was given for each gender: in IFG, 0.6894 (male) and 0.5392 (female), in MFG, 0.6487 (male) and 0.5713 (female), and in SFG: 0.8042(male) and 0.7436(female). To test ability of the lower bound to differentiate between healthy adults and adults with neurological disorders (showing weaker RSFC), 15 patients with affective disorders or sleep disorder were recruited for the resting state scan. The results showed that IFG was the most predictive ROI. This study may help to establish a quantitative range of RSFC for healthy adults and serve as a reference for screening patients with neurological disorders.

Optical Mapping of Brain Activation and Connectivity in Occipitotemporal Cortex During Chinese Character Recognition.

Hu Z, Zhang J, Couto TA, Xu S, Luan P, Yuan Z.

Brain Topogr. Jun
doi: 10.1007/s10548-018-0650-y. [Epub ahead of print]

In this study, functional near-infrared spectroscopy (fNIRS) was used to examine the brain activation and connectivity in occipitotemporal cortex during Chinese character recognition (CCR). Eighteen healthy participants were recruited to perform a well-designed task with three categories of stimuli (real characters, pseudo characters, and checkerboards). By inspecting

the brain activation difference and its relationship with behavioral data, the left laterality during CCR was clearly identified in the Brodmann area (BA) 18 and 19. In addition, our novel findings also demonstrated that the bilateral superior temporal gyrus (STG), bilateral BA 19, and left fusiform gyrus were also involved in high-level lexical information processing such as semantic and phonological ones. Meanwhile, by examining functional brain networks, we discovered that the right BA 19 exhibited enhanced brain connectivity. In particular, the connectivity in the right fusiform gyrus, right BA 19, and left STG showed significant correlation with the performance of CCR. Consequently, the combination of fNIRS technique with functional network analysis paves a new avenue for improved understanding of the cognitive mechanism underlying CCR.

Moderating Effect of White Matter Integrity on Brain Activation During Dual-Task Walking in Older Adults.

Lucas M, Wagshul ME, Izzetoglu M, Holtzer R.

J Gerontol A Biol Sci Med Sci. Jun
doi: 10.1093/gerona/gly[Epub ahead of print]

Objectives: Using multi-modal neuroimaging methods the current study was designed to examine the relationship between white matter microstructural integrity (WMI) and changes in prefrontal cortex (PFC) oxygenated hemoglobin (HbO2) during active walking in older adults. Consistent with neural inefficiency, we hypothesized that worse WMI would be associated with a greater increase in PFC HbO2 from single- to dual-task walking in the context of worse or similar gait performance. Method: 55 cognitively-healthy older adults (mean age=74.76 years, 49% women) underwent Diffusion Tensor Imaging (DTI) to derive a whole-brain measure of Fractional Anisotropy (FA) and functional Near Infrared Spectroscopy (fNIRS), which measured PFC HbO2 during walking tasks. Gait velocity was assessed using an instrumented walkway. Results: A linear mixed effects model revealed that HbO2 levels increased from single to dual-task walking ($p<0.01$) given the greater cognitive demands inherent in the latter condition. Moreover, WMI moderated the effect of dual-tasking on PFC HbO2 ($p<0.05$). Specifically, worse WMI was associated with a larger increase in PFC HbO2 levels from single to dual-task walking in the context of similar gait velocity. Conclusion: Results suggest that compromised WMI may be a mechanism underlying inefficient brain response to cognitive demands of locomotion.

fNIRS reveals enhanced brain activation to female (versus male) infant directed speech (relative to adult directed speech) in Young Human Infants.

Sulpizio S, Doi H, Bornstein MH, Cui J, Esposito G, Shinohara K.

Infant Behav Dev. Aug;52:89-
doi: 10.1016/j.infbeh.2018.05.Epub 2018 Jun 14.

We hypothesized an association between auditory stimulus structure and activity in the brain that underlies infant auditory preference. In a within-infant design, we assessed brain activity to female and male infant directed relative to adult directed speech in 4-month-old infants using fNIRS. Results are compatible with the hypothesis that enhanced frontal brain activation, specifically in prefrontal cortex that is involved in emotion and reward, is evoked selectively by infant directed speech produced by female voices and may serve as a neuronal substrate for attention to and preference for "motherese" displayed by infants.

Towards using fNIRS recordings of mental arithmetic for the detection of residual cognitive activity in patients with disorders of consciousness (DOC).

Kurz EM, Wood G, Kober SE, Schippinger W, Pichler G, Mller-Putz G, Bauernfeind G.

Brain Cogn. Aug;125:78-
doi: 10.1016/j.bandc.2018.06.Epub Jun 14.

BACKGROUND: Recently, fNIRS has been proposed as a promising approach for awareness detection, and a possible method to establish basic communication in patients with disorders of consciousness (DOC). AIM: Using fNIRS, the present study evaluated the applicability of auditory presented mental-arithmetic tasks in this respect. METHODS: We investigated the applicability of active attention to serial subtractions for awareness detection in ten healthy controls (HC, 21-32 y/o), by comparing the measured patterns to patterns induced by self-performance of the same task. Furthermore, we examined the suitability of ignoring the given task as additional control signal to implement a two-class brain-computer interface (BCI) paradigm. Finally, we compared our findings in HC with recordings in one DOC patient (78 y/o). RESULTS AND CONCLUSION: Results of the HC revealed no differences between the self-performance and the atten-

tion condition, making the attention task suitable for awareness detection. However, there was no general difference between the ignore and attend condition, making the tasks less suitable for BCI control. Despite inconsistent correlations between the patient data and the HC group, single runs of the patient recordings revealed task-synchronous patterns - however, we cannot conclude whether the measured activation derives from instruction based task performance and thus awareness.

Cortical activity during walking and balance tasks in older adults and in people with Parkinson's disease: A structured review.

Stuart S, Vitorio R, Morris R, Martini DN, Fino PC, Mancini M.

Maturitas. Jul;113:53-
doi: 10.1016/j.maturitas.2018.04.Epub 2018 Apr 25.

An emerging body of literature has examined cortical activity during walking and balance tasks in older adults and in people with Parkinson's disease, specifically using functional near infrared spectroscopy (fNIRS) or electroencephalography (EEG). This review provides an overview of this developing area, and examines the disease-specific mechanisms underlying walking or balance deficits. Medline, PubMed, PsychInfo and Scopus databases were searched. Articles that described cortical activity during walking and balance tasks in older adults and in those with PD were screened by the reviewers. Thirty-seven full-text articles were included for review, following an initial yield of 566 studies. This review summarizes study findings, where increased cortical activity appears to be required for older adults and further for participants with PD to perform walking and balance tasks, but specific activation patterns vary with the demands of the particular task. Studies attributed cortical activation to compensatory mechanisms for underlying age- or PD-related deficits in automatic movement control. However, a lack of standardization within the reviewed studies was evident from the wide range of study protocols, instruments, regions of interest, outcomes and interpretation of outcomes that were reported. Unstandardized data collection, processing and reporting limited the clinical relevance and interpretation of study findings. Future work to standardize approaches to the measurement of cortical activity during walking and balance tasks in older adults and people with PD with fNIRS and EEG systems is needed, which will allow direct comparison of results and ensure robust data collection/reporting. Based on the reviewed articles we provide clinical and

future research recommendations.

Eye contact modulates facial mimicry in 4-month-old infants: An EMG and fNIRS study.

de Klerk CCJM, Hamilton AFC, Southgate V.

Cortex. Sep;106:93-
doi: 10.1016/j.cortex.2018.05.Epub May 16.

Mimicry, the tendency to spontaneously and unconsciously copy others' behaviour, plays an important role in social interactions. It facilitates rapport between strangers, and is flexibly modulated by social signals, such as eye contact. However, little is known about the development of this phenomenon in infancy, and it is unknown whether mimicry is modulated by social signals from early in life. Here we addressed this question by presenting 4-month-old infants with videos of models performing facial actions (e.g., mouth opening, eyebrow raising) and hand actions (e.g., hand opening and closing, finger actions) accompanied by direct or averted gaze, while we measured their facial and hand muscle responses using electromyography to obtain an index of mimicry (Experiment 1). In Experiment 2 the infants observed the same stimuli while we used functional near-infrared spectroscopy to investigate the brain regions involved in modulating mimicry by eye contact. We found that 4-month-olds only showed evidence of mimicry when they observed facial actions accompanied by direct gaze. Experiment 2 suggests that this selective facial mimicry may have been associated with activation over posterior superior temporal sulcus. These findings provide the first demonstration of modulation of mimicry by social signals in young human infants, and suggest that mimicry plays an important role in social interactions from early in life.

Mind over motor mapping: Driver response to changing vehicle dynamics.

Bruno JL, Baker JM, Gundran A, Harbott LK, Stuart Z, Piccirilli AM, Hosseini SMH, Gerdes JC, Reiss AL.

Hum Brain Mapp. Oct;39(10):3915-
doi: 10.1002/hbm.Epub Jun 8.

Improvements in vehicle safety require understanding of the neural systems that support the complex, dynamic task of real-world driving. We used

functional near infrared spectroscopy (fNIRS) and pupilometry to quantify cortical and physiological responses during a realistic, simulated driving task in which vehicle dynamics were manipulated. Our results elucidate compensatory changes in driver behavior in response to changes in vehicle handling. We also describe associated neural and physiological responses under different levels of mental workload. The increased cortical activation we observed during the late phase of the experiment may indicate motor learning in prefrontal-parietal networks. Finally, relationships among cortical activation, steering control, and individual personality traits suggest that individual brain states and traits may be useful in predicting a driver's response to changes in vehicle dynamics. Results such as these will be useful for informing the design of automated safety systems that facilitate safe and supportive driver-car communication.

Hemoglobin state-flux: A finite-state model representation of the hemoglobin signal for evaluation of the resting state and the influence of disease.

Barbour RL, Graber HL, Barbour SS.

PLoS One. Jun 8;13(6):e
doi: 10.1371/journal.pone.0198210. eCollection 2018.

SUMMARY: In this report we introduce a weak-model approach for examination of the intrinsic time-varying properties of the hemoglobin signal, with the aim of advancing the application of functional near infrared spectroscopy (fNIRS) for the detection of breast cancer, among other potential uses. The developed methodology integrates concepts from stochastic network theory with known modulatory features of the vascular bed, and in doing so provides access to a previously unrecognized dense feature space that is shown to have promising diagnostic potential. Notable features of the methodology include access to this information solely from measures acquired in the resting state, and analysis of these by treating the various components of the hemoglobin (Hb) signal as a co-varying interacting system. APPROACH: The principal data-transform kernel projects Hb state-space trajectories onto a coordinate system that constitutes a finite-state representation of covariations among the principal elements of the Hb signal (i.e., its oxygenated (?oxyHb) and deoxygenated (?deoxyHb) forms and the associated dependent quantities: total hemoglobin (?totalHb = ?oxyHb + ?deoxyHb), hemoglobin oxygen saturation (?HbO2Sat = 100?(oxyHb/totalHb)), and tissue-hemoglobin oxygen exchange (?HbO2Exc = ?deoxyHb-?oxyHb)).

The resulting ten-state representation treats the evolution of this signal as a one-space, spatiotemporal network that undergoes transitions from one state to another. States of the network are defined by the algebraic signs of the amplitudes of the time-varying components of the Hb signal relative to their temporal mean values. This assignment produces several classes of coefficient arrays, most with a dimension of 1010. BIOLOGICAL MOTIVATION: Motivating our approach is the understanding that effector mechanisms that modulate blood delivery to tissue operate on macroscopic scales, in a spatially and temporally varying manner. Also recognized is that this behavior is sensitive to nonlinear actions of these effectors, which include the binding properties of hemoglobin. Accessible phenomenology includes measures of the kinetics and probabilities of network dynamics, which we treat as surrogates for the actions of feedback mechanisms that modulate tissue-vascular coupling. FINDINGS: Qualitative and quantitative features of this space, and their potential to serve as markers of disease, have been explored by examining continuous-wave fNIRS 3D tomographic time series obtained from the breasts of women who do and do not have breast cancer. Inspection of the coefficient arrays reveals that they are governed predominantly by first-order rate processes, and that each array class exhibits preferred structure that is mainly independent of the others. Discussed are strategies that may serve to extend evaluation of the accessible feature space and how the character of this information holds potential for development of novel clinical and preclinical uses.

An fNIRS-Based Feature Learning and Classification Framework to Distinguish Hemodynamic Patterns in Children Who Stutter.

Hosseini R, Walsh B, Tian F, Wang S.

IEEE Trans Neural Syst Rehabil Eng. Jun;26(6):1254-
doi: 10.1109/TNSRE.2018.2829083.

DOI: 10.1109/TNSRE.2018.2829083 PMCID: PMC6242270 [Available on 2019-06-01] PMID: 29877850

Which is more costly in Chinese to English simultaneous interpreting, "pairing" or "transphrasing"? Evidence from an fNIRS neuroimaging study.

Lin X, Lei VLC, Li D, Yuan Z.
Neurophotonics. Apr;5(2):
doi: 10.1117/1.NPh.5.2.Epub 2018 Jun 5.

This study examined the neural mechanism underlying two translation strategies associated with Chinese to English simultaneous interpreting (SI) targeting the left prefrontal cortex (PFC), which is generally involved in the control of interference and conflict resolution and has been identified as the brain area that plays a pivotal role in SI. Brain activation associated with the two strategies including "pairing" and "transphrasing" were compared with that from "nontranslation," which keeps the source language item unchanged in the target language production and is considered as a tactic that does not require complex cognitive operation associated with bilingual processing effort. Our findings revealed that "pairing" elicited the strongest and almost immediate brain activation in the Broca's area, and "transphrasing" resulted in the most extensive and strongest activation overall in the left PFC. By contrast, "nontranslation" induced very little brain activation in these regions. This work, which represents one of the first efforts in investigating brain activation related to translation strategies involving different levels of cognitive control, will not only pave a new avenue for better understanding of the cognitive mechanism underlying SI but also provide further insight into the role that the Broca's region plays in domain-general cognitive control.

Developmental changes in cortical sensory processing during wakefulness and sleep.

Taga G, Watanabe H, Homae F.
Neuroimage. Sep;178:519-
doi: 10.1016/j.neuroimage.2018.05.Epub May 31.

Infants are exposed to auditory and visual information during sleep as well as wakefulness. Little is known, however, about the differences in cortical processing of sensory input between these different behavioral states. In the present study, cortical hemodynamic responses to auditory and visual stimuli during wakefulness and sleep were measured in infants aged 2-10 months using functional near-infrared spectroscopy (fNIRS). While asynchronously presented auditory and visual stimuli during wakefulness induced focal responses in the corresponding sensory regions of the occipital and temporal cortices, the responses to the same stimuli during sleep were dramatically different. Auditory stimuli during sleep induced global responses

over the frontal, temporal, and occipital regions, and the response pattern did not change between 2 and 10 months of age. In contrast, visual stimuli during sleep induced responses in the occipital cortex, and the response pattern exhibited developmental changes from a pattern of activation to one of deactivation around a half year of age. The functional connectivity among the cortical regions was generally higher during sleep than during wakefulness. The hemoglobin phase of oxygenation and deoxygenation (hPod) and the phase locking index of hPod (hPodL) showed general developmental changes and behavioral state dependent differences but no significant differences were seen between the stimulus types. The results suggest that the behavioral states have a fundamental impact on cortical sensory processing; (1) sensory processing during wakefulness is performed in more localized regions, (2) auditory processing is active during both wakefulness and sleep, (3) visual processing undergoes development of inhibitory mechanisms during sleep, and (4) these phenomena primarily reflect neural development rather than vascular and metabolic development.

The effect of diabetes on prefrontal cortex activation patterns during active walking in older adults.

Holtzer R, George CJ, Izzetoglu M, Wang C.

Brain Cogn. Aug;125:14-
doi: 10.1016/j.bandc.2018.03.Epub May 25.

BACKGROUND: Gait alterations were documented in diabetic patients. However, the effect of diabetes on cortical control of gait has not been reported. We evaluated the effect of diabetes on prefrontal cortex (PFC) Oxygenated Hemoglobin (HbO2) levels during active walking in older adults. METHODS: Of the total sample (n = 315; mean age = 76.84 6.71ys; % female = 56.5) 43 participants (13.7%) had diabetes. The experimental paradigm consisted of two single tasks: Normal-Walk (NW); and Cognitive Interference (Alpha); and one dual-task condition consisting of the two single tasks, Walk-While-Talk (WWT). Functional Near-Infrared-Spectroscopy (fNIRS) was used to quantify PFC HbO2 levels. RESULTS: Older adults without diabetes showed higher PFC HbO2 levels in WWT compared to both NW and Alpha. HbO2 levels during NW were not different between the two groups. Consistent with Neural Inefficiency, older adults with diabetes exhibited higher HbO2 levels during Alpha while performing significantly worse than those without diabetes. Moreover, the presence of diabetes was associated with attenuated HbO2 levels during WWT. This pattern is consis-

tent with Capacity Limitations suggesting a failure to recruit brain resources vis–vis the more cognitively challenging WWT condition. CONCLUSIONS: A distinct functional neural signature of diabetes was established during active and attention demanding walking among older adults without overt neurological disease.

Brain-to-brain synchrony in parent-child dyads and the relationship with emotion regulation revealed by fNIRS-based hyperscanning.

Reindl V, Gerloff C, Scharke W, Konrad K.

Neuroimage. Sep;178:493-
doi: 10.1016/j.neuroimage.2018.05.Epub May 26.

Parent-child synchrony, the coupling of behavioral and biological signals during social contact, may fine-tune the child's brain circuitries associated with emotional bond formation and the child's development of emotion regulation. Here, we examined the neurobiological underpinnings of these processes by measuring parent's and child's prefrontal neural activity concurrently with functional near-infrared spectroscopy hyperscanning. Each child played both a cooperative and a competitive game with the parent, mostly the mother, as well as an adult stranger. During cooperation, parent's and child's brain activities synchronized in the dorsolateral prefrontal and frontopolar cortex (FPC), which was predictive for their cooperative performance in subsequent trials. No significant brain-to-brain synchrony was observed in the conditions parent-child competition, stranger-child cooperation and stranger-child competition. Furthermore, parent-child compared to stranger-child brain-to-brain synchrony during cooperation in the FPC mediated the association between the parent's and the child's emotion regulation, as assessed by questionnaires. Thus, we conclude that brain-to-brain synchrony may represent an underlying neural mechanism of the emotional connection between parent and child, which is linked to the child's development of adaptive emotion regulation. Future studies may uncover whether brain-to-brain synchrony can serve as a neurobiological marker of the dyad's socio-emotional interaction, which is sensitive to risk conditions, and can be modified by interventions.

Optical mapping of prefrontal brain connectivity and activa-

tion during emotion anticipation.

Wang MY, Lu FM, Hu Z, Zhang J, Yuan Z.

Behav Brain Res. Sep 17;350:122-
doi: 10.1016/j.bbr.2018.04.Epub May 9.

Accumulated neuroimaging evidence shows that the dorsal lateral prefrontal cortex (dlPFC) is activated during emotion anticipation. The aim of this work is to examine the brain connectivity and activation differences in dlPFC between the positive, neutral and negative emotion anticipation by using functional near-infrared spectroscopy (fNIRS). The hemodynamic responses were first assessed for all subjects during the performance of various emotion anticipation tasks. And then small-world analysis was performed, in which the small-world network indicators including the clustering coefficient, average path length, average node degree, and measure of small-world index were calculated for the functional brain networks associated with the positive, neutral and negative emotion anticipation, respectively. We discovered that compared to negative and neutral emotion anticipation, the positive one exhibited enhanced brain activation in the left dlPFC. Although the functional brain networks for the three emotion anticipation cases manifested the small-world properties regarding the clustering coefficient, average path length, average node degree, and measure of small-world index, the positive one showed significantly higher clustering coefficient and shorter average path length than those from the neutral and negative cases. Consequently, the small-world network indicators and brain activation in dlPPC were able to distinguish well between the positive, neutral and negative emotion anticipation.

Assessment of fecal near-infrared spectroscopy to predict feces chemical composition and apparent total-tract digestibility of nutrients in pigs.

Nirea KG, Prez de Nanclares M, Skugor A, Afseth NK, Meuwissen THE, Hansen J, Mydland LT, verland M.

J Anim Sci. Jun 29;96(7):2826-
doi: 10.1093/jas/sky182.

Apparent total-tract digestibility (ATTD) of nutrients could be an alternative measure of feed efficiency (FE) when breeding for robust animals that are fed fiber-rich diets. Apparent total-tract digestibility of nutrients requires measuring individual feed intake of a large number of animals which is expensive and complex. Alternatively, ATTD of nutrients and feces chem-

ical composition can be predicted using fecal near-infrared reflectance spectroscopy (FNIRS). The objective of this study was to assess if the feces chemical composition and ATTD of nutrients can be predicted using FNIRS that originate from various pig-experimental datasets. Fecal samples together with detailed information on the feces chemical composition and ATTD of nutrients were obtained from four different pig experiments. Feces near-infrared spectroscopy was analyzed from fecal samples of a complete dataset. The model was calibrated using the FNIRS and reference samples of feces chemical composition and ATTD of nutrients. The robustness and predictability of the model were evaluated by the r2 and the closeness between SE of calibration (SEC) and SE of cross-validation (SECV). Prediction of the feces chemical components and ATTD of nutrients were successful as SEC and SECV were equivalent. Calibration model was developed to estimate the ATTD of nutrients and fecal chemical composition from the FNIRS and worked well for OM (r2 = 0.94; SEC = 48.5; SECV = 56.6), CP (r2 = 0.89; SEC = 18.1; SECV = 18.8), GE (r2 = 0.92; SEC = 1.2; SECV = 1.4), NDF (r2 = 0.94; SEC = 55; SECV = 60.2), OM digestibility (r2 = 0.94; SEC = 5.5; SECV = 6.7), GE digestibility (r2 = 0.88; SEC = 2.3; SECV = 2.6), and fat digestibility (r2 = 0.79; SEC = 6, SECV = 6.8). However, the SE of prediction was slightly higher than what has been reported in another study. The prediction of feces chemical composition for fat (r2 = 0.69; SEC = 11.7, SECV = 12.3), CP digestibility (r2 = 0.63; SEC = 2.3; SECV = 2.7), and NDF digestibility (r2 = 0.64, SEC = 7.7, SECV = 8.8) was moderate. We conclude that the FNIRS accurately predicts the chemical composition of feces and ATTD of nutrients for OM, CP, and GE. The approach of FNIRS is a cost-effective method for measuring digestibility and FE in a large-scale pig-breeding programs.

A functional near infrared spectroscopy (fNIRS) replication of the sunscreen persuasion paradigm.

Burns SM, Barnes LN, Katzman PL, Ames DL, Falk EB, Lieberman MD.
Soc Cogn Affect Neurosci. Jun 1;13(6):628-
doi: 10.1093/scan/nsy030.

Activity in medial prefrontal cortex (mPFC) during persuasive messages predicts future message-consistent behavior change, but there are significant limitations to the types of persuasion processes that can be invoked inside an MRI scanner. For instance, real world persuasion often involves multiple people in conversation. Functional near infrared spectroscopy (fNIRS)

allows us to move out of the scanner and into more ecologically valid contexts. As a first step, the current study used fNIRS to replicate an existing fMRI persuasion paradigm (i.e. the sunscreen paradigm) to determine if mPFC shows similar predictive value with this technology. Consistent with prior fMRI work, activity in mPFC was significantly associated with message-consistent behavior change, above and beyond self-reported intentions. There was also a difference in this association between previous users and non-users of sunscreen. Activity differences based on messages characteristics were not observed. Finally, activity in a region of right dorsolateral PFC (dlPFC), which has been observed with counterarguing against persuasive messages, correlated negatively with future behavior. The current results suggest it is reasonable to use fNIRS to examine persuasion paradigms that go beyond what is possible in the MRI scanner environment.

Critical bounds on noise and SNR for robust estimation of real-time brain activity from functional near infra-red spectroscopy.

Aqil M, Jeong MY.

Neuroimage. Aug 1;176:321-
doi: 10.1016/j.neuroimage.2018.04.Epub Apr 24.

The robust characterization of real-time brain activity carries potential for many applications. However, the contamination of measured signals by various instrumental, environmental, and physiological sources of noise introduces a substantial amount of signal variance and, consequently, challenges real-time estimation of contributions from underlying neuronal sources. Functional near infra-red spectroscopy (fNIRS) is an emerging imaging modality whose real-time potential is yet to be fully explored. The objectives of the current study are to (i) validate a time-dependent linear model of hemodynamic responses in fNIRS, and (ii) test the robustness of this approach against measurement noise (instrumental and physiological) and mis-specification of the hemodynamic response basis functions (amplitude, latency, and duration). We propose a linear hemodynamic model with time-varying parameters, which are estimated (adapted and tracked) using a dynamic recursive least square algorithm. Owing to the linear nature of the activation model, the problem of achieving robust convergence to an accurate estimation of the model parameters is recast as a problem of parameter error stability around the origin. We show that robust convergence of the proposed method is guaranteed in the presence of an acceptable degree of

model misspecification and we derive an upper bound on noise under which reliable parameters can still be inferred. We also derived a lower bound on signal-to-noise-ratio over which the reliable parameters can still be inferred from a channel/voxel. Whilst here applied to fNIRS, the proposed methodology is applicable to other hemodynamic-based imaging technologies such as functional magnetic resonance imaging.

The emergence of top-down, sensory prediction during learning in infancy: A comparison of full-term and preterm infants.
Boldin AM, Geiger R, Emberson LL.
Dev Psychobiol. Jul;60(5):544-
doi: 10.1002/dev.Epub Apr 24.

Prematurity alters developmental trajectories in preterm infants even in the absence of medical complications. Here, we use fNIRS and learning tasks to probe the nature of the developmental differences between preterm and full-term born infants. Our recent work has found that prematurity disrupts the ability to engage in top-down sensory prediction after learning. We now examine the neural changes during the learning that precede prediction. In full-terms, we found modulation of all cortical regions examined during learning (temporal, frontal, and occipital). By contrast, preterm infants had no evidence of neural changes in the occipital lobe selectively. This is striking as the learning task leads to the emergence of visual prediction. Moreover, the shape of individual infants' occipital lobe trajectories (regardless of prematurity) predicts subsequent visual prediction abilities. These results suggest that modulation of sensory cortices during learning is closely related to the emergence of top-down signals and further indicates that developmental differences in premature infants may be associated with deficits in top-down processing.

Dynamic causal modelling on infant fNIRS data: A validation study on a simultaneously recorded fNIRS-fMRI dataset.
Bulgarelli C, Blasi A, Arridge S, Powell S, de Klerk CCJM, Southgate V, Brigadoi S, Penny W, Tak S, Hamilton A.
Neuroimage. Jul 15;175:413-
doi: 10.1016/j.neuroimage.2018.04.Epub Apr 12.

Tracking the connectivity of the developing brain from infancy through

childhood is an area of increasing research interest, and fNIRS provides an ideal method for studying the infant brain as it is compact, safe and robust to motion. However, data analysis methods for fNIRS are still underdeveloped compared to those available for fMRI. Dynamic causal modelling (DCM) is an advanced connectivity technique developed for fMRI data, that aims to estimate the coupling between brain regions and how this might be modulated by changes in experimental conditions. DCM has recently been applied to adult fNIRS, but not to infants. The present paper provides a proof-of-principle for the application of this method to infant fNIRS data and a demonstration of the robustness of this method using a simultaneously recorded fMRI-fNIRS single case study, thereby allowing the use of this technique in future infant studies. fMRI and fNIRS were simultaneously recorded from a 6-month-old sleeping infant, who was presented with auditory stimuli in a block design. Both fMRI and fNIRS data were preprocessed using SPM, and analysed using a general linear model approach. The main challenges that adapting DCM for fNIRS infant data posed included: (i) the import of the structural image of the participant for spatial pre-processing, (ii) the spatial registration of the optodes on the structural image of the infant, (iii) calculation of an accurate 3-layer segmentation of the structural image, (iv) creation of a high-density mesh as well as (v) the estimation of the NIRS optical sensitivity functions. To assess our results, we compared the values obtained for variational Free Energy (F), Bayesian Model Selection (BMS) and Bayesian Model Average (BMA) with the same set of possible models applied to both the fMRI and fNIRS datasets. We found high correspondence in F, BMS, and BMA between fMRI and fNIRS data, therefore showing for the first time high reliability of DCM applied to infant fNIRS data. This work opens new avenues for future research on effective connectivity in infancy by contributing a data analysis pipeline and guidance for applying DCM to infant fNIRS data.

Cortical Processing Related to Intensity of a Modulated Noise Stimulus-a Functional Near-Infrared Study.

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

J Assoc Res Otolaryngol. Jun;19(3):273-
doi: 10.1007/s10162-018-0661- Epub Apr 9.

Sound intensity is a key feature of auditory signals. A profound understanding of cortical processing of this feature is therefore highly desirable. This study investigates whether cortical functional near-infrared

spectroscopy (fNIRS) signals reflect sound intensity changes and where on the brain cortex maximal intensity-dependent activations are located. The fNIRS technique is particularly suitable for this kind of hearing study, as it runs silently. Twenty-three normal hearing subjects were included and actively participated in a counterbalanced block design task. Four intensity levels of a modulated noise stimulus with long-term spectrum and modulation characteristics similar to speech were applied, evenly spaced from 15 to 90dB SPL. Signals from auditory processing cortical fields were derived from a montage of 16 optodes on each side of the head. Results showed that fNIRS responses originating from auditory processing areas are highly dependent on sound intensity level: higher stimulation levels led to higher concentration changes. Caudal and rostral channels showed different waveform morphologies, reflecting specific cortical signal processing of the stimulus. Channels overlying the supramarginal and caudal superior temporal gyrus evoked a phasic response, whereas channels over Broca's area showed a broad tonic pattern. This data set can serve as a foundation for future auditory fNIRS research to develop the technique as a hearing assessment tool in the normal hearing and hearing-impaired populations.

Improving the analysis of near-infrared spectroscopy data with multivariate classification of hemodynamic patterns: a theoretical formulation and validation.

Gemignani J, Middell E, Barbour RL, Graber HL, Blankertz B.

J Neural Eng. Aug;15(4):

doi: 10.1088/1741-2552/aabb7c. Epub Apr 4.

OBJECTIVE: The statistical analysis of functional near infrared spectroscopy (fNIRS) data based on the general linear model (GLM) is often made difficult by serial correlations, high inter-subject variability of the hemodynamic response, and the presence of motion artifacts. In this work we propose to extract information on the pattern of hemodynamic activations without using any a priori model for the data, by classifying the channels as 'active' or 'not active' with a multivariate classifier based on linear discriminant analysis (LDA). APPROACH: This work is developed in two steps. First we compared the performance of the two analyses, using a synthetic approach in which simulated hemodynamic activations were combined with either simulated or real resting-state fNIRS data. This procedure allowed for exact quantification of the classification accuracies of GLM and LDA. In the case of real resting-state data, the correlations between

classification accuracy and demographic characteristics were investigated by means of a Linear Mixed Model. In the second step, to further characterize the reliability of the newly proposed analysis method, we conducted an experiment in which participants had to perform a simple motor task and data were analyzed with the LDA-based classifier as well as with the standard GLM analysis. MAIN RESULTS: The results of the simulation study show that the LDA-based method achieves higher classification accuracies than the GLM analysis, and that the LDA results are more uniform across different subjects and, in contrast to the accuracies achieved by the GLM analysis, have no significant correlations with any of the demographic characteristics. Findings from the real-data experiment are consistent with the results of the real-plus-simulation study, in that the GLM-analysis results show greater inter-subject variability than do the corresponding LDA results. SIGNIFICANCE: The results obtained suggest that the outcome of GLM analysis is highly vulnerable to violations of theoretical assumptions, and that therefore a data-driven approach such as that provided by the proposed LDA-based method is to be favored.

Prefrontal over-activation during walking in people with mobility deficits: Interpretation and functional implications.

Hawkins KA, Fox EJ, Daly JJ, Rose DK, Christou EA, McGuirk TE, Otzel DM, Butera KA, Chatterjee SA, Clark DJ.

Hum Mov Sci. Jun;59:46-
doi: 10.1016/j.humov.2018.03.Epub Mar 29.

BACKGROUND: Control of walking by the central nervous system includes contributions from executive control mechanisms, such as attention and motor planning resources. Executive control of walking can be estimated objectively by recording prefrontal cortical activity using functional near infrared spectroscopy (fNIRS). OBJECTIVE: The primary objective of this study was to investigate group differences in prefrontal/executive control of walking among young adults, older adults, and adults post-stroke. Also assessed was the extent to which walking-related prefrontal activity fits existing cognitive frameworks of prefrontal over-activation. METHODS: Participants included 24 adults post-stroke with moderate to severe walking deficits, 15 older adults with mild gait deficits, and 9 young healthy adults. Executive control of walking was quantified as oxygenated hemoglobin concentration in the prefrontal cortex measured by fNIRS. Three walking tasks were assessed: typical walking, walking over obstacles, and walking while

performing a verbal fluency task. Walking performance was assessed by walking speed. RESULTS: There was a significant effect of group for prefrontal activity ($p < 0.001$) during typical and obstacles walking tasks, with young adults exhibiting the lowest level of prefrontal activity, followed by older adults, and then adults post-stroke. In young adults the prefrontal activity during typical walking was much lower than for the verbal fluency dual-task, suggesting substantial remaining prefrontal resources during typical walking. However, in older and post-stroke adults these remaining resources were significantly less ($p < 0.01$). Cumulatively, these results are consistent with prefrontal over-activation in the older and stroke groups, which was accompanied by a steeper drop in walking speed as task complexity increased to include obstacles ($p < 0.05$). CONCLUSIONS: There is a heightened use of prefrontal/executive control resources in older adults and post-stroke adults during walking. The level of prefrontal resource utilization, particularly during complex walking tasks like obstacle crossing, may approach the ceiling of available resources for people who have walking deficits. Prior cognitive research has revealed that prefrontal over-activation combined with limited prefrontal resources can lead to poor cognitive performance. The present study suggests a similar situation influences walking performance. Future research should further investigate the extent to which prefrontal over-activation during walking is linked to adverse mobility outcomes.

Linguistic and motor representations of everyday complex actions: an fNIRS investigation.

Crivelli D, Sabogal Rueda MD, Balconi M.

Brain Struct Funct. Jul;223(6):2989-
doi: 10.1007/s00429-018-1646-9. Epub Mar 12.

The present work aimed at exploring functional correlates of motor and linguistic representations of everyday actions, with a specific interest in potential sensorimotor activation effects induced by the use of related action sentences. While it is indeed known that observing simple motor acts (e.g., precision grasping) and listening to the sound of specific actions (e.g., walking) activate sensorimotor structures, less is known when we move to more complex behaviors and more abstract linguistic representations (e.g., verbal descriptions). Again, the potential of linguistic representations to facilitate the activation of specific sensorimotor structures during action execution or observation is yet unexplored. We then aimed at investigating hemody-

namic activation patterns (via functional near-infrared spectroscopy, fNIRS) within the sensorimotor network during different tasks based on everyday activities. Twenty volunteers were asked to execute (EXE), observe (OBS), or listen (LIS) to brief verbal descriptions of transitive actions, to observe them while listening to their description (OBS-LIS), or to execute them while listening to their description (EXE-LIS). Analyses highlighted that, in the left hemisphere, hemodynamic responses were the lowest during observation of complex actions and observation coupled with listening, greater during simple listening to verbal description of actions, and maximal when participants actually executed complex actions or executed them while listening to their verbal descriptions. The present results suggest that processing verbal descriptions of actions might keep the sensorimotor network more active than simply observing them. Such first pieces of evidence hint at potential implications for novel procedures for rehabilitation of movement and action deficits.

The neural correlates of arithmetic difficulty depend on mathematical ability: evidence from combined fNIRS and ERP.
Artemenko C, Soltanlou M, Dresler T, Ehlis AC, Nuerk HC.
Brain Struct Funct. Jul;223(6):2561-
doi: 10.1007/s00429-018-1618-0. Epub Mar 10.

Mathematical abilities are essential for an individual, as they predict career prospects among many other abilities. However, little is known about whether neural correlates of arithmetic problem difficulty differ between individuals with high and low math ability. For instance, the difficulty of two-digit addition and subtraction increases whenever a carry or borrow operation is required. Therefore, we systematically investigated the spatial and temporal neural correlates of the carry and borrow effects for high and low performers in a written production paradigm using combined functional near-infrared spectroscopy (fNIRS) and event-related potential (ERP) measurements. Effects of arithmetic difficulty interacted with an individual's math ability. High performers showed increased frontal activation especially in the left inferior frontal gyrus associated with the carry and borrow effects, whereas low performers did not. Furthermore, high and low performers even differed in their early processing of the borrow effect, as reflected by differences in slow waves at 1000-1500ms at frontal sites. We conclude that the processing of arithmetic difficulty relies on an individual's mathematical ability, and suggest that individual differences should be taken into account

when investigating mental arithmetic in an ecologically valid assessment.

Functional brain connectivity when cooperation fails.
Balconi M, Vanutelli ME, Gatti L.
Brain Cogn. Jun;123:65-
doi: 10.1016/j.bandc.2018.02.Epub Mar 8.

Functional connectivity during cooperative actions is an important topic in social neuroscience that has yet to be answered. Here, we examined the effects of administration of (fictitious) negative social feedback in relation to cooperative capabilities. Cognitive performance and neural activation underlying the execution of joint actions was recorded with functional near-infrared spectroscopy (fNIRS) on prefrontal regions during a task where pairs of participants received negative feedback after their joint action. Performance (error rates (ERs) and response times (RTs)) and intra- and inter-brain connectivity indices were computed, along with the ConIndex (inter-brain/intra-brain connectivity). Finally, correlational measures were considered to assess the relation between these different measures. Results showed that the negative feedback was able to modulate participants' responses for both behavioral and neural components. Cognitive performance was decreased after the feedback. Moreover, decreased inter-brain connectivity and increased intra-brain connectivity was induced by the feedback, whereas the cooperative task pre-feedback condition was able to increase the brain-to-brain coupling, mainly localized within the dorsolateral prefrontal cortex (DLPFC). Finally, the presence of significant correlations between RTs and inter-brain connectivity revealed that ineffective joint action produces the worst cognitive performance and a more 'individual strategy' for brain activity, limiting the inter-brain connectivity. The present study provides a significant contribution to the identification of patterns of intra- and inter-brain functional connectivity when negative social reinforcement is provided in relation to cooperative actions.

Cortical activation patterns to spatially presented pure tone stimuli with different intensities measured by functional near-infrared spectroscopy.
Bauernfeind G, Wriessnegger SC, Haumann S, Lenarz T.
Hum Brain Mapp. Jul;39(7):2710-

doi: 10.1002/hbm.Epub Mar 8.

Functional near-infrared spectroscopy (fNIRS) is an emerging technique for the assessment of functional activity of the cerebral cortex. Recently fNIRS was also envisaged as a novel neuroimaging approach for measuring the auditory cortex activity in the field of in auditory diagnostics. This study aimed to investigate differences in brain activity related to spatially presented sounds with different intensities in 10 subjects by means of functional near-infrared spectroscopy (fNIRS). We found pronounced cortical activation patterns in the temporal and frontal regions of both hemispheres. In contrast to these activation patterns, we found deactivation patterns in central and parietal regions of both hemispheres. Furthermore our results showed an influence of spatial presentation and intensity of the presented sounds on brain activity in related regions of interest. These findings are in line with previous fMRI studies which also reported systematic changes of activation in temporal and frontal areas with increasing sound intensity. Although clear evidence for contralaterality effects and hemispheric asymmetries were absent in the group data, these effects were partially visible on the single subject level. Concluding, fNIRS is sensitive enough to capture differences in brain responses during the spatial presentation of sounds with different intensities in several cortical regions. Our results may serve as a valuable contribution for further basic research and the future use of fNIRS in the area of central auditory diagnostics.

Diffuse near-infrared imaging of tissue with picosecond time resolution.

Grosenick D, Wabnitz H, Macdonald R.

Biomed Tech (Berl). Oct 25;63(5):511-
doi: 10.1515/bmt-2017-0067.

Optical imaging of biological tissue in vivo at multiple wavelengths in the near-infrared (NIR) spectral range can be achieved with picosecond time resolution at high sensitivity by time-correlated single photon counting. Measuring and analyzing the distribution of times of flight of photons randomly propagated through the tissue has been applied for diffuse optical imaging and spectroscopy, e.g. of human breast tissue and of the brain. In this article, we review the main features and the potential of NIR multispectral imaging with picosecond time resolution and illustrate them by exemplar applications in these fields. In particular, we discuss the experimental methods developed at the Physikalisch-Technische Bundesanstalt (PTB) to

record optical mammograms and to quantify the absorption and scattering properties from which hemoglobin concentration and oxygen saturation of healthy and diseased breast tissue have been derived by combining picosecond time-domain and spectral information. Furthermore, optical images of functional brain activation were obtained by a non-contact scanning device exploiting the null source-detector separation approach which takes advantage of the picosecond time resolution as well. The recorded time traces of changes in the oxy- and deoxyhemoglobin concentrations during a motor stimulation investigation show a localized response from the brain.

Real-time monitoring prefrontal activities during online video game playing by functional near-infrared spectroscopy.

Li Y, Zhang L, Long K, Gong H, Lei H.

J Biophotonics. Sep;11(9):e
doi: 10.1002/jbio.Epub 2018 Jun 5.

A growing body of literature has suggested that video game playing can induce functional and structural plasticity of the brain. The underlying mechanisms, however, remain poorly understood. In this study, functional near-infrared spectroscopy (fNIRS) was used to record prefrontal activities in 24 experienced game players when they played a massively multiplayer online battle arena video game, League of Legends (LOL), under naturalistic conditions. It was observed that game onset was associated with significant activations in the ventrolateral prefrontal cortex (VLPFC) and concomitant deactivations in the dorsolateral prefrontal cortex (DLPFC) and frontal pole area (FPA). Game events, such as slaying an enemy and being slain by an enemy evoked region-specific time-locked hemodynamic/oxygenation responses in the prefrontal cortex (PFC). It was proposed that the VLPFC activities during LOL playing are likely responses to visuo-motor task load of the game, while the DLPFC/FPA activities may be involved in the constant shifts of attentional states and allocation of cognitive resources required by game playing. The present study demonstrated that it is feasible to use fNIRS to monitor real-time prefrontal activity during online video game playing.

Deep learning for hybrid EEG-fNIRS brain-computer interface: application to motor imagery classification.

Chiarelli AM, Croce P, Merla A, Zappasodi F.
J Neural Eng. Jun;15(3):
doi: 10.1088/1741-2552/aaafEpub Feb 15.

OBJECTIVE: Brain-computer interface (BCI) refers to procedures that link the central nervous system to a device. BCI was historically performed using electroencephalography (EEG). In the last years, encouraging results were obtained by combining EEG with other neuroimaging technologies, such as functional near infrared spectroscopy (fNIRS). A crucial step of BCI is brain state classification from recorded signal features. Deep artificial neural networks (DNNs) recently reached unprecedented complex classification outcomes. These performances were achieved through increased computational power, efficient learning algorithms, valuable activation functions, and restricted or back-fed neurons connections. By expecting significant overall BCI performances, we investigated the capabilities of combining EEG and fNIRS recordings with state-of-the-art deep learning procedures. APPROACH: We performed a guided left and right hand motor imagery task on 15 subjects with a fixed classification response time of 1?s and overall experiment length of 10?min. Left versus right classification accuracy of a DNN in the multi-modal recording modality was estimated and it was compared to standalone EEG and fNIRS and other classifiers. MAIN RESULTS: At a group level we obtained significant increase in performance when considering multi-modal recordings and DNN classifier with synergistic effect. SIGNIFICANCE: BCI performances can be significantly improved by employing multi-modal recordings that provide electrical and hemodynamic brain activity information, in combination with advanced non-linear deep learning classification procedures.

Variability of the hemodynamic response in infants: Influence of experimental design and stimulus complexity.

Issard C, Gervain J.
Dev Cogn Neurosci. Oct;33:182-
doi: 10.1016/j.dcn.2018.01.Epub 2018 Feb 4.

Measuring brain activity in developmental populations remains a major challenge despite great technological advances. Among the numerous available methods, functional near-infrared spectroscopy (fNIRS), an imaging modality that probes the hemodynamic response, is a powerful tool for recording brain activity in a great variety of situations and populations. Neurocognitive studies with infants have often reported inverted hemody-

namic responses, i.e. a decrease instead of an increase in regional blood oxygenation, but the exact physiological explanation and cognitive interpretation of this response remain unclear. Here, we first provide an overview of the basic principles of NIRS and its use in cognitive developmental neuroscience. We then review the infant fNIRS literature to show that the hemodynamic response is modulated by experimental design and stimulus complexity, sometimes leading to hemodynamic responses with non-canonical shapes. We also argue that this effect is further modulated by the age of participants, the cortical regions involved, and the developmental stage of the tested cognitive process. We argue that this variability needs to be taken into account when designing and interpreting developmental studies measuring the hemodynamic response.

Reduced Functional Connectivity in Adults with Persistent Post-Concussion Symptoms: A Functional Near-Infrared Spectroscopy Study.

Hocke LM, Duszynski CC, Debert CT, Dleikan D, Dunn JF.

J Neurotrauma. Jun 1;35(11):1224-
doi: 10.1089/neu.2017.Epub 2018 Mar 23.

Concussion, or mild traumatic brain injury (mTBI), accounts for 80% of all TBIs across North America. The majority of mTBI patients recover within days to weeks; however, 14-36% of the time, acute mTBI symptoms persist for months or even years and develop into persistent post-concussion symptoms (PPCS). There is a need to find biomarkers in patients with PPCS, to improve prognostic ability and to provide insight into the pathophysiology underlying chronic symptoms. Recent research has pointed toward impaired network integrity and cortical communication as a biomarker. In this study we investigated functional near-infrared spectroscopy (fNIRS) as a technique to assess cortical communication deficits in adults with PPCS. Specifically, we aimed to identify cortical communication patterns in prefrontal and motor areas during rest and task, in adult patients with persistent symptoms. We found that (1) the PPCS group showed reduced connectivity compared with healthy controls, (2) increased symptom severity correlated with reduced coherence, and (3) connectivity differences were best distinguishable during task and in particular during the working memory task (n-back task) in the right and left dorsolateral prefrontal cortex (DLPFC). These data show that reduced brain communication may be associated with the pathophysiology of mTBI and that fNIRS, with a rela-

tively simple acquisition paradigm, may provide a useful biomarker of this injury.

Altered cortical activation and connectivity patterns for visual attention processing in young adults post-traumatic brain injury: A functional near infrared spectroscopy study.

Wu Z, Mazzola CA, Catania L, Owoeye O, Yaramothu C, Alvarez T, Gao Y, Li X.

CNS Neurosci Ther. Jun;24(6):539-
doi: 10.1111/cns.Epub Jan 22.

AIMS: This study aimed at understanding the neurobiological mechanisms associated with inattention induced by traumatic brain injury (TBI). To eliminate the potential confounding caused by the heterogeneity of TBI, we focused on young adults postsports-related concussion (SRC). METHODS: Functional near-infrared spectroscopy (fNIRS) data were collected from 27 young adults post-SRC and 27 group-matched normal controls (NCs), while performing a visual sustained attention task. Task responsive cortical activation maps and pairwise functional connectivity among six regions of interest were constructed for each subject. Correlations among the brain imaging measures and clinical measures of attention were calculated in each group. RESULTS: Compared to the NCs, the SRC group showed significantly increased brain activation in left middle frontal gyrus (MFG) and increased functional connectivity between right inferior occipital cortex (IOC) bilateral calcarine gyri (CG). The left MFG activation magnitude was significantly negatively correlated with the hyperactive/impulsive symptom severity measure in the NCs, but not in the patients. The right hemisphere CG-IOC functional connectivity showed a significant positive correlation with the hyperactive/impulsive symptom severity measure in patients, but not in NCs. CONCLUSION: The current data suggest that abnormal left MFG activation and hyper-communications between right IOC and bilateral CG during visual attention processing may significantly contribute to behavioral manifestations of attention deficits in patients with TBI.

Association of Fine Motor Loss and Allodynia in Fibromyalgia: An fNIRS Study.

Eken A, Gkay D, Yilmaz C, Baskak B, Baltaci A, Kara M.

J Mot Behav. Nov-Dec;50(6):664-
doi: 10.1080/00222895.2017.Epub Dec 6.
Erratum in J Mot Behav. 2018 Nov-Dec;50(6):x.

Identifying ADHD children using hemodynamic responses during a working memory task measured by functional near-infrared spectroscopy.

Gu Y, Miao S, Han J, Liang Z, Ouyang G, Yang J, Li X.

J Neural Eng. Jun;15(3):
doi: 10.1088/1741-2552/aa9eeEpub Dec 4.

OBJECTIVE: Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder affecting children and adults. Previous studies found that functional near-infrared spectroscopy (fNIRS) can reveal significant group differences in several brain regions between ADHD children and healthy controls during working memory tasks. This study aimed to use fNIRS activation patterns to identify ADHD children from healthy controls. APPROACH: FNIRS signals from 25 ADHD children and 25 healthy controls performing the n-back task were recorded; then, multivariate pattern analysis was used to discriminate ADHD individuals from healthy controls, and classification performance was evaluated for significance by the permutation test. MAIN RESULTS: The results showed that 86.0% ([Formula: see text]) of participants can be correctly classified in leave-one-out cross-validation. The most discriminative brain regions included the bilateral dorsolateral prefrontal cortex, inferior medial prefrontal cortex, right posterior prefrontal cortex, and right temporal cortex. SIGNIFICANCE: This study demonstrated that, in a small sample, multivariate pattern analysis can effectively identify ADHD children from healthy controls based on fNIRS signals, which argues for the potential utility of fNIRS in future assessments.

Light up ADHD: I. Cortical hemodynamic responses measured by functional Near Infrared Spectroscopy (fNIRS): Special Section on "Translational and Neuroscience Studies in Affective Disorders" Section Editor, Maria Nobile MD, PhD. This Section of JAD focuses on the relevance of translational and neuroscience studies in providing a better understanding of the neural basis of affective disorders. The main aim is to

briefly summarise relevant research findings in clinical neuroscience with particular regards to specific innovative topics in mood and anxiety disorders.

Mauri M, Nobile M, Bellina M, Crippa A, Brambilla P.

J Affect Disord. Jul;234:358-
doi: 10.1016/j.jad.2017.11.Epub Nov 21.

BACKGROUND: Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by deficits in cognitive and emotional self-control. Optical technique acquisitions, such as near infrared spectroscopy (NIRS), seem to be very promising during developmental ages, as they are non- invasive techniques and less influenced by body movements than other neuroimaging methods. Recently, these new techniques are being widely used to measure neural correlates underlying neuropsychological deficits in children with ADHD. METHODS: In a short series of articles, we will review the results of functional NIRS (fNIRS) studies in children with ADHD. The present brief review will focus on the results of the fNIRS studies that investigate cortical activity during neuropsychological and/or emotional tasks. RESULTS: According to the reviewed studies, children and adolescents with ADHD show peculiar cortical activation both during neurological and emotional tasks, and the majority of the reviewed studies revealed lower prefrontal cortex activation in patients compared to typically developmental controls. LIMITATIONS: a consistent interpretation of these results is limited by the substantial methodological heterogeneity including patients' medication status and washout period, explored cerebral regions, neuropsychological tasks, number of channels and sampling temporal resolutions. CONCLUSIONS: fNIRS seems to be a promising tool for investigating neural substrates of emotional dysregulation and executive function deficits in individuals with ADHD during developmental ages.

Functional near-infrared spectroscopy to probe sensorimotor region activation during electrical stimulation-evoked movement.

Muthalib M, Ferrari M, Quaresima V, Kerr G, Perrey S.

Clin Physiol Funct Imaging. Sep;38(5):816-
doi: 10.1111/cpf.Epub Nov 7.

This study used non-invasive functional near-infrared spectroscopy (fNIRS) neuroimaging to monitor bilateral sensorimotor region activation during unilateral voluntary (VOL) and neuromuscular electrical stimulation (NMES)-

evoked movements.METHODS: In eight healthy male volunteers, fNIRS was used to measure relative changes in oxyhaemoglobin (O2 Hb) and deoxyhaemoglobin (HHb) concentrations from a cortical sensorimotor region of interest in the left (LH) and right (RH) hemispheres during NMES-evoked and VOL wrist extension movements of the right arm. RESULTS: NMES-evoked movements induced significantly greater activation (increase in O2 Hb and concomitant decrease in HHb) in the contralateral LH than in the ipsilateral RH (O2 Hb: 044016M and 025022M, P=0017; HHb: -019010M and -012009M, P=0036, respectively) as did VOL movements (051024 ? and 034021M, P=0031; HHb: -018007 ? and -012004 ?, P=005, respectively). There was no significant difference between conditions for O2 Hb (P=0144) and HHb (P=0958). CONCLUSION: fNIRS neuroimaging enables quantification of bilateral sensorimotor regional activation profiles during voluntary and NMES-evoked wrist extension movements.

Cortical Responses to Alien Odors in Newborns: An fNIRS Study.

Frie J, Bartocci M, Lagercrantz H, Kuhn P.

Cereb Cortex. Sep 1;28(9):3229-
doi: 10.1093/cercor/bhx194.

Very preterm (VPT) infants are exposed to odors released by healthcare products, triggering the trigeminal and olfactory subsystems. Irritation of the nasal mucosa induces pain in adults. We examined whether preterm and full-term (FT) newborns perceived trigeminal odors at different cortical levels, whether these odors elicit pain, and if oral glucose modulates this pain. We performed 44 recording sessions in newborn (15 VPT infants, 12 VPT infants at term-equivalent age, and 17 FT infants) following exposure to trigeminal/olfactory stimuli from the hospital environment. We repeated the exposure after oral glucose administration. We recorded cortical activation in the olfactory, frontal, and somatosensory cortices by functional near-infrared spectroscopy, and analyzed pain behaviors from videotaped recordings. Newborns integrated trigeminal/olfactory stimuli in trigeminal/olfactory and nociceptive processing areas beginning at 31 weeks postmenstrual age, and also exhibited pain behaviors. Pain scores were positively associated with the level of cortical activation. Oral glucose inhibited pain behaviors and cortical activation. There were developmental differences in cortical integration related to brain maturation and duration of the extrauterine experience. In conclusion, VPT and FT infants showed trigeminal

sensitivity after exposure to alien odors that induce pain, potentially affecting the wiring of the neuronal circuits of the newborn brain.

Assessing autism at its social and developmental roots: A review of Autism Spectrum Disorder studies using functional near-infrared spectroscopy.

Liu T, Liu X, Yi L, Zhu C, Markey PS, Pelowski M.

Neuroimage. Jan 15;185:955-
doi: 10.1016/j.neuroimage.2017.09.Epub Sep 28.

We review a relatively new method for studying the developing brain in children and infants with Autism Spectrum Disorder (ASD). Despite advances in behavioral screening and brain imaging, due to paradigms that do not easily allow for testing of awake, very young, and socially-engaged children-i.e., the social and the baby brain-the biological underpinnings of this disorder remain a mystery. We introduce an approach based on functional near-infrared spectroscopy (fNIRS), which offers a noninvasive imaging technique for studying functional activations by measuring changes in the brain's hemodynamic properties. This further enables measurement of brain activation in upright, interactive settings, while maintaining general equivalence to fMRI findings. We review the existing studies that have used fNIRS for ASD, discussing their promise, limitations, and their technical aspects, gearing this study to the researcher who may be new to this technique and highlighting potential targets for future research.

Using individual functional channels of interest to study cortical development with fNIRS.

Powell LJ, Deen B, Saxe R.

Dev Sci. Jul;21(4):e
doi: 10.1111/desc.Epub Sep 24.

Functional near-infrared spectroscopy (fNIRS) is a noninvasive neuroimaging technique that could be uniquely effective for investigating cortical function in human infants. However, prior efforts have been hampered by the difficulty of aligning arrays of fNIRS optodes placed on the scalp to anatomical or functional regions of underlying cortex. This challenge can be addressed by identifying channels of interest in individual participants, and then testing the reliability of those channels' response profiles in indepen-

dent data. Using this approach, cortical regions with preferential responses to faces versus scenes, and to scenes versus faces, were observed reliably in both adults and infants. By contrast, standard analysis techniques did not reliably identify significant responses to both categories in either age group. These results reveal scene-responsive regions, and confirm face-responsive regions, in preverbal infants. More generally, the analysis approach will be a robust and sensitive tool for future characterization of the early functional development of the human brain.

Focal Hemodynamic Responses in the Stimulated Hemisphere During High-Definition Transcranial Direct Current Stimulation.

Muthalib M, Besson P, Rothwell J, Perrey S.

Neuromodulation. Jun;21(4):348-
doi: 10.1111/ner.Epub Jul 17.

OBJECTIVE: High-definition transcranial direct current stimulation (HD-tDCS) using a 4 1 electrode montage has been previously shown using modeling and physiological studies to constrain the electric field within the spatial extent of the electrodes. The aim of this proof-of-concept study was to determine if functional near-infrared spectroscopy (fNIRS) neuroimaging can be used to determine a hemodynamic correlate of this 4 1 HD-tDCS electric field on the brain. MATERIALS AND METHODS: In a three session cross-over study design, 13 healthy males received one sham (2 mA, 30 sec) and two real (HD-tDCS-1 and HD-tDCS-2, 2 mA, 10 min) anodal HD-tDCS targeting the left M1 via a 4 1 electrode montage (anode on C3 and 4 return electrodes 3.5 cm from anode). The two real HD-tDCS sessions afforded a within-subject replication of the findings. fNIRS was used to measure changes in brain hemodynamics (oxygenated hemoglobin integral-O2 Hbint) during each 10 min session from two regions of interest (ROIs) in the stimulated left hemisphere that corresponded to "within" (Lin) and "outside" (Lout) the spatial extent of the 4 1 electrode montage, and two corresponding ROIs (Rin and Rout) in the right hemisphere. RESULTS: The ANOVA showed that both real anodal HD-tDCS compared to sham induced a significantly greater O2 Hbint in the Lin than Lout ROIs of the stimulated left hemisphere; while there were no significant differences between the real and sham sessions for the right hemisphere ROIs. Intra-class correlation coefficients showed "fair-to-good" reproducibility for the left stimulated hemisphere ROIs. CONCLUSIONS: The greater O2 Hbint "within" than

"outside" the spatial extent of the 4 1 electrode montage represents a hemodynamic correlate of the electrical field distribution, and thus provides a prospective reliable method to determine the dose of stimulation that is necessary to optimize HD-tDCS parameters in various applications.

Does ventrolateral prefrontal cortex help in searching for the lost key? Evidence from an fNIRS study.

Carrieri M, Lancia S, Bocchi A, Ferrari M, Piccardi L, Quaresima V.

Brain Imaging Behav. Jun;12(3):785-
doi: 10.1007/s11682-017-9734-7.

The Key Search Task (KST) is a neuropsychological test that requires strategies for searching a lost key in an imaginary field. This request may involve different cognitive processes as mental imagery and navigation planning. This study was aimed at investigating, by a twenty-channel functional near-infrared spectroscopy (fNIRS) system, the hemodynamic response (i.e., oxygenated-hemoglobin (O2Hb) and deoxygenated-hemoglobin (HHb) changes) of the prefrontal cortex in navigation planning. A right ventrolateral prefrontal cortex (rVLPFC) activation during the KST was hypothesized. Thirty-eight volunteers performed the KST and a Control Task (CT), the latter requiring the volunteers to mark the X letter. An activation (i.e., increase/decrease in O2Hb/HHb) of: 1) rVLPFC during the KST execution, and 2) bilateral dorsolateral prefrontal cortex (DLPFC) during the CT execution was found. The present study provides a contribution in localizing the rVLPFC as the critically active region, within the frontal lobes, that was found maximally activated during mental navigation in the mind's eye of healthy participants while performing the KST. Considering the contribution of rVLPFC in spatial navigation, its activation suggests that the KST could be adopted in the clinical routine for investigating navigation planning. Compared to other neuroimaging techniques, fNIRS (with its relatively low physical constraints) contributes to better clarifying the role of rVLPFC in some aspects of human navigation. Therefore, the combined use of the fNIRS and the KST could be considered as an innovative and valid tool to evaluate fundamental functions for everyday life, such as spatial navigation planning.