Hemodynamic spectral signatures across vigilance states: a whole-night EEG/fNIRS investigation

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Abstract: We propose whole-night EEG/fNIRS, targeting bilateral frontoparietal regions, to investigate cortical oscillations of oxyhemoglobin (HbO) during sleep. 13 healthy subjects underwent whole night EEG/fNIRS. We applied Morse analytical wavelet to characterize the oscillatory modes of oxyhemoglobin in different sleep stages, while removing the aperiodic 1/f component. We found sleep-state-specific signatures of hemodynamic oscillations in frontal and parietal regions, including REM phasic and tonic state. We are reporting for the first-time sleep-state-specific spectral signatures of HbO oscillations, as a promising approach to characterize physiological and pathological sleep.

Introduction: Sleep includes Rapid-Eye-Movement (REM) and Non-REM sleep stages, the latter further classified in N1, N2, N3 stages from light to deep sleep. Sleep stages are defined by specific EEG signatures, whereas EEG rhythms are also associated with brain hemodynamic activity. Recent EEG/fMRI studies revealed distinct oscillations in regional blood-oxygen-level-dependent signal at 0.04-0.07Hz during N2 correlated with spindles and at 0.15-0.18Hz during N3 correlated with slow waves (Song et al., 2022). Whereas EEG/fMRI sleep studies are difficult to complete (immobility constraints, noise, limited duration), simultaneous EEG/fNIRS emerges as a promising multimodal approach for whole night sleep monitoring. However, due to limitations such as short sleep recordings or limited spatial coverage, the physiology of sleep-related hemodynamic processes and their spatio-temporal organizations remains poorly understood. We propose all-night personalized EEG/fNIRS, using an optimized locally dense montage targeting bilateral frontoparietal regions, to investigate HbO oscillations during sleep in healthy subjects. **Method:** 13 subjects underwent whole night EEG/fNIRS. Sleep staging of EEG data was based on American Academy of Sleep Medicine manual. We applied our fNIRS workflow (Cai et al. 2021), optimizing the position of fNIRS sensors to target bilateral frontoparietal regions (2 light sources and 4 detectors per region). After applying standard fNIRS pre-processing, we applied time-frequency analysis using Morse analytical wavelet, using the Taeger-Kaiser normalization to disentangle oscillatory from aperiodic (1/f) components of HbO signals. HbO time-frequency results were considered to estimate HbO power spectra for each stable sleep state, including for the first-time REM phasic and tonic states. To assess whether relative changes of hemodynamic power during each sleep state (vs wakefulness) were significant, general linear mixed effect model has been applied. Similar time-frequency analysis was applied to auxiliary signals. **Results:** Our results, based on 13 subjects (6 females, 18-35 years, mean sleep efficiency:90.3%), show sleep-state-specific signatures of hemodynamic oscillations in frontal and parietal regions. In frontal region, compared to wakefulness, N3 showed increase oxyhemoglobin power in respiratory band (~0.2Hz) and reduced power around 0.004-0.013Hz. N2 exhibited increased oscillatory power in respiratory band ~0.2Hz. REM sleep was characterized by overall increases in frequencies <0.15 Hz and respiratory-band oscillations. Both REM tonic and phasic states exhibited increased power in (<0.15 Hz) and respiratory band, with tonic REM showing a larger peak around 0.2Hz. Complementary analysis of auxiliary signals revealed dominant oscillatory component in pulse oximetry at ~0.2Hz and cardiac band (~1Hz), MAP at vasomotor ~0.1Hz and respiration belt at ~0.2Hz, suggesting that sleep-stage-specific hemodynamic oscillations were not solely driven by systemic physiology. **Conclusion:** Whole-night personalized EEG/fNIRS appears as a new promising modality to study sleep physiology, suggesting that sleep-stage-specific hemodynamic signatures could be used to further characterize NREM and REM sleep in healthy and pathological conditions.
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Neural Signatures of Cognitive Decline: Insights from Fronto-Motor Connectivity

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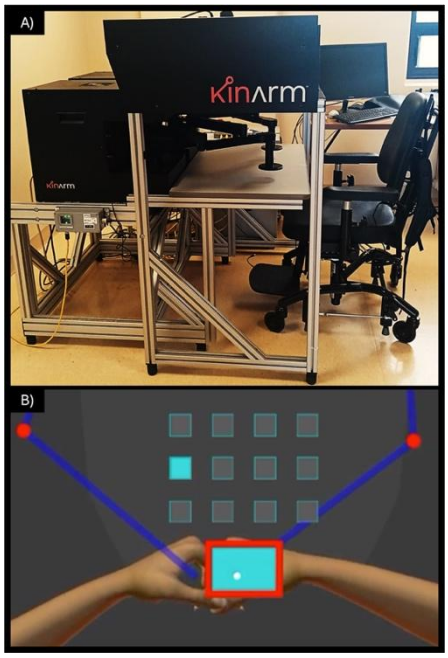
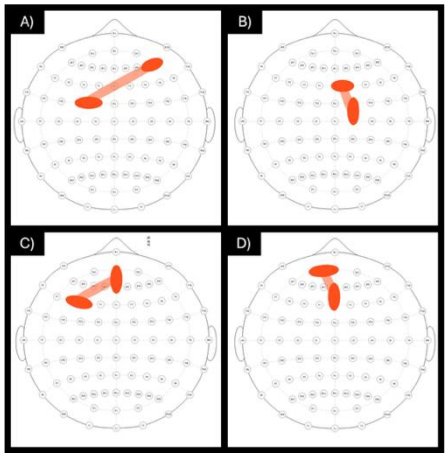
Abstract: How the brain changes across the dementia spectrum remains unclear. This uncertainty is compounded by the fact that people diagnosed with mild cognitive impairment, the first clinical classification on the dementia spectrum, may remain stable or even revert to cognitively "healthy." Probing functional connectivity – the temporal synchrony of activation between distinct brain regions – during a cognitive-motor task that more closely reflects real-world complexity may help provide clarity. Compared to cognitively healthy participants, those living with mild cognitive impairment exhibited weaker functional connectivity:

1) between prefrontal and sensorimotor regions; and
2) within the prefrontal cortex.



Introduction: Functional connectivity (FC) reflects brain areas that are anatomically separate but temporally synchronized in their activation.[1] FC enables the completion of complex functions, and alterations in FC precede structural atrophy and the clinical manifestation of cognitive impairment.[2,3] How exactly FC changes across the dementia spectrum is unclear.[4] Here, we compared FC in cognitively "healthy" older adults versus those with probable mild cognitive impairment during a complex cognitive-motor task.

Methods: Using Kinarm, an interactive robotic device (BKIN Technologies, Canada; Top panel – A), we immersed participants in a virtual environment while they completed a task ("Spatial Span;" Top panel – B) that simultaneously tested executive function and upper-limb motor control. During the task, we measured brain activity via functional near-infrared spectroscopy to examine group (i.e., healthy versus impaired) differences in FC. We quantified brain activity in both chromophores: oxygenated and deoxygenated. To minimize type one error, FC was considered significantly different if group differences appeared in both chromophores.



Results: Participants (n=34) showed differences in global cognition as per the Montreal Cognitive Assessment (27.22±1.00 vs. 22.60±1.35; $p<0.001$), but no other characteristics (e.g., age, years of education, etc.). The healthy group demonstrated stronger FC between prefrontal and sensorimotor regions, including: 1) right primary motor – dorsomedial prefrontal cortex; and 2) left premotor – right ventrolateral prefrontal cortex ($p<0.05$; Bottom panel: A & B). Healthy participants also demonstrated stronger FC within the prefrontal cortex, including: 1) the left inferior frontal gyrus – frontal pole; and 2) left frontal pole – dorsomedial prefrontal cortex ($p<0.05$; Bottom panel: C & D).

Conclusion: Compared to those with mild cognitive impairment, cognitively healthy older adults exhibited stronger FC between prefrontal and sensorimotor regions and within the prefrontal cortex while

completing our virtual cognitive-motor task. Our findings help clarify the physiological transitions from cognitively healthy to impaired and may help identify those at the greatest risk of disease progression – current priorities in dementia research.[5]

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Learning to Read After Displacement: Neurocognitive Correlates of Literacy in Syrian Refugee Children and Youth

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Abstract: We examined the impact of displacement and disrupted education on literacy development in Syrian refugee children and youth resettled in Canada. One hundred participants (M_{age} = 13.78) underwent fNIRS while completing a print- and speech-processing task, and completed standardized assessments of language and literacy skills. Length and age of disruption were distinctly related to activation in the reading network in the brain. Activation for print was related to reading comprehension, suggesting that compensatory neural recruitment beyond the typical left-lateralised reading network. A cluster analysis showed distinct reading profiles that were predicted by neural activation and displacement metrics.

Introduction: Since 2015, over 80,000 refugees from Syria have resettled in Canada, with over half of them being minors. Refugee children and youth are vulnerable educationally, socio-emotionally, and physically, and lag behind not only their peers, but also other English language learners (ELLs), in measures of literacy. While ELL's L2 literacy skills typically catch up to their peers' skills within 3-5 years post-resettlement, recent findings suggest that this same improvement may not be occurring as expected among refugee children (Al Janaideh, 2020). To understand this phenomenon, our study examined the long-term literacy outcomes of Syrian refugee children.

As children learn to read, the brain's language and visual systems are reorganized, forming a specialized neural system that supports skilled reading (Dehaene et al., 2015). These neural changes are not predetermined but emerge through experience, with literacy instruction and exposure to print playing a critical role in shaping how the reading network develops. While the neural reading network is well-established in typically developing populations with continuous access to quality education at a standard age (Pugh et al., 2001), less is known about how these neural networks develop to support literacy when formal instruction is disrupted or delayed.

Methods: One hundred participants who had resettled in Canada under the Syrian refugee programme were recruited for the study. Participants were aged between 8 and 18, and had been in Canada between 1 and 13 years. fNIRS was collected during a passive print and speech processing paradigm, with participants exposed to words, pseudowords and false font/vocoded stimuli in visual and auditory modalities. A battery of standardised English language (vocabulary and phonological awareness) and literacy (word and pseudoword reading, passage comprehension) skills were administered, as well as an adapted version of the Alberta Language Environment Questionnaire-4 to gather information about their language environment and displacement experiences.

Results & Conclusions: Neural activation for print processing was related to literacy outcomes, but stronger literacy was associated with greater the right hemisphere, suggesting compensatory recruitment of right hemisphere analogues that typically show a reduction in involvement in reading among fluent readers. Age of displacement was associated with right hemisphere activation while length of displacement was related to the tradeoff between frontal and parietal activation. A cluster analysis found a number of distinct reading profiles, that were predicted by neural activation and displacement experiences. These results show that the developmental timing of instruction for literacy plays a crucial role in the development of typical reading networks for fluent literacy, and has implications for interventions to support literacy in refugee youth.

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Infant Brain Activity in a Naturalistic Sensorimotor Task

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Abstract: Sensorimotor development in infants is characterized by the transition from random to coordinated movements. To understand how cortical networks reorganize to support this change we used functional near infrared spectroscopy (fNIRS) to measure brain activity in developing infants. We used a naturalistic task, leading to a variety of motor behaviours, which were manually coded and used for a finite impulse response (FIR) model. As infants' motor coordination develops the cortical activity in the parietal regions becomes more active and transitions from bilateral to unilateral as handedness develops.

Introduction: The writhing movements of young infants gradually reorganise into purposeful actions [1], which requires substantial alterations in sensorimotor, perceptual, and cognitive processes [2]. Numerous theories aim to explain how cortical networks might reorganise to support these changes [2], but a comprehensive description of the neural changes that accompany sensorimotor development in early infancy is largely absent [3]. Progress has been impeded by conventional research paradigms that are difficult to implement with infants and interfere with natural behaviour and brain activity. We combined ethological research design principles with wireless functional near infrared spectroscopy (fNIRS) to monitor spontaneous cortical activity in a large longitudinal sample of freely behaving infants while they played and reached for food items. Our main hypothesis was that as infants develop sensorimotor skills the corresponding parietal cortex activity should mirror this pattern.

Methods: 30 infants from ages 6 – 13 months participated in a longitudinal reach-to-grasp task and a free play task. Multiple behaviours (reach, grasp, kick, dancing, mouthing, bobbing, watching, etc.) were manually coded using BORIS [4] and were integrated into the FIR model for analysis. fNIRS was recorded using the Brite system from Artinis [5 The Netherlands, www.artinis.com], with 22 channels split bilaterally covering the parietal cortex. First, we identified fNIRS motion artifacts by running temporal derivative distribution repair filtering [6], then a wavelet filter, [7]. We extracted heart rate using NeuroKit2 [8], as this method worked better for our data than power spectral density. Channel pruning was decided by both scalp coupling index and peak spectral power [9,10]. We then converted NIRS raw data to optical density [11], calculated the hemoglobin concentration, and finally ran a FIR model [12] on ages 6-7 months, 8-10 months and 11-13 months.

Results: Preliminary results show that as infants age, they display increased activity in parietal regions during reaching behaviour. This supports the idea that as the movements become structured the parietal cortex, which controls the visuomotor integration of the reach to grasp movement, is more active to support this development. Further, we also see lateralization starting to emerge as the infants reach 12 months of age, with the left hemisphere dominating activity at 12 months while bilateral activity predominates at 6 months. Finally, our naturalistic task has enabled us to explore a variety of other behaviours such as dancing, kicking, and mouthing so we can now also examine the neural activity associated with the early development of these behaviours in playing infants.

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Interpersonal Brain Synchrony in Mother-Child Social Interactions in Autistic and Non-autistic Children

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Abstract: Autistic children often face social challenges, yet many form secure attachments with caregivers. This study examined neural synchrony as a mechanism underlying attachment in autism. Using fNIRS, we measured mother–child neural synchrony during cooperative and individual puzzle tasks targeting the prefrontal cortex and temporoparietal junction. Thirty dyads (7 autistic, 23 non-autistic; *M* = 10.2 years) were analyzed. Both groups showed higher synchrony in matched than random dyads. Non-autistic dyads showed higher synchrony during cooperation, while autistic dyads did not. Synchrony correlated positively with attachment scores in both groups. Findings suggest attachment quality may be captured brain-to-brain coupling across groups.

Introduction: Although autistic children often face challenges in social interactions, many are still able to form secure attachments with their caregivers. However, the neural mechanisms underlying attachment in autism remain underexplored. The present study examined mother–child neural synchrony and its association with attachment security to investigate the neural correlates of attachment in autistic children.

Methods: Functional near-infrared spectroscopy (fNIRS) was used to assess neural synchrony between mothers and their children during a structured puzzle-play task that included two conditions: Cooperation ("work together") and Individual ("work independently"). The task primarily targeted the prefrontal cortex (PFC) and temporoparietal junction (TPJ). After completing the task, mothers filled out the Child–Parent Relationship Scale (CPRS) and children completed the Inventory of Parent and Peer Attachment–Revised (IPPA) to assess the level of attachment security. Data collection is ongoing; this preliminary analysis included 30 school-aged children (7 autistic, 23 non-autistic; M = 10.22 years).

Results: Both autistic and non-autistic dyads showed higher neural synchrony in matched (true) pairs than in random pairs (Figure 1). Non-autistic dyads demonstrated a trend toward greater synchrony in the Cooperation than in the Individual condition, whereas autistic dyads did not show this pattern (Figure 2). Nevertheless, in both groups, neural synchrony during the Cooperation condition tended to be positively associated with attachment security scores.

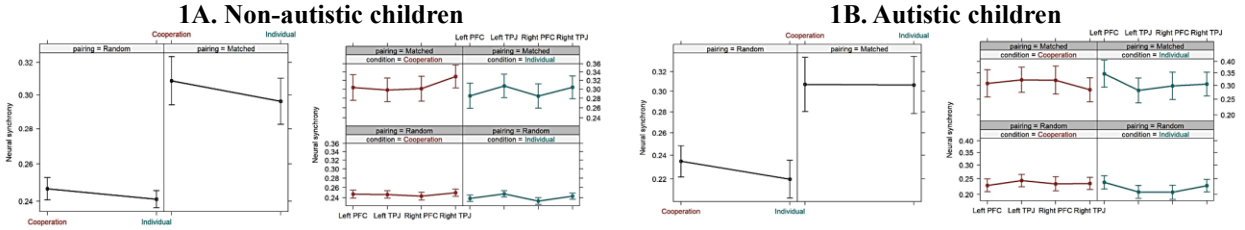

Figure 1. Neural synchrony between Matched and Random dyads in non-autistic (1A) and autistic (1B) children

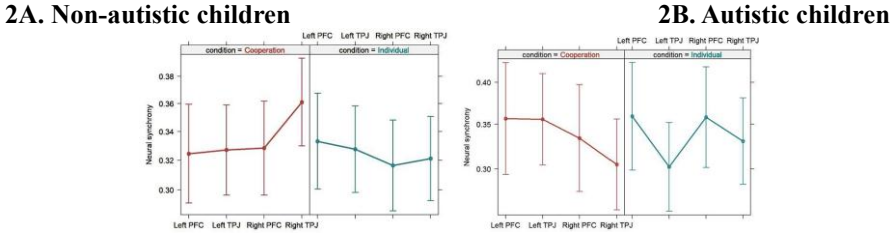

Figure 2. Neural synchrony in bilateral PFCs and TPJs during "Cooperation" and "Individual" conditions in non-autistic (2A) and autistic (2B) children

Conclusions: These preliminary findings may reflect atypical neural organization in autistic children, although replication with a larger sample is needed. The observed trends linking higher neural synchrony with greater attachment security suggest that attachment quality may play an important role in shaping brain-to-brain coupling across both groups. These results highlight the potential of attachment-based interventions to support social brain development in autistic children.

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fNIRS and fMRI Responses to Median Nerve Stimulation: Validation in Controls and Translation to the ICU

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Abstract: This study compares fNIRS and fMRI sensitivity to median nerve stimulation in healthy individuals and explores fNIRS as a bedside tool for unresponsive ICU patients. Twenty-five controls completed counterbalanced fMRI and fNIRS sessions. fMRI consistently detected activity in somatosensory cortices, while fNIRS showed lower but substantial sensitivity (23/25 left hand, 20/25 right hand). Proof-of-concept ICU cases demonstrated variable neural responses, ranging from strong to absent. These findings suggest that although less sensitive than fMRI, fNIRS can capture stimulation-evoked activity and may provide a practical, accessible means of assessing neural function in patients unable to undergo fMRI.

Introduction: Predicting recovery after severe acute brain injury is a significant clinical and scientific challenge. Current prognostic tools – such as median nerve stimulation paired with EEG – can identify patients with poor prognosis yet lack the ability to predict good recovery due to limited insight into the extent of neural responses. However, combining median nerve stimulation with functional neuroimaging techniques like fMRI and fNIRS may provide a more comprehensive assessment of neural activity beyond what can be detected with EEG. This ongoing study first validates fNIRS sensitivity against fMRI in healthy individuals and explores the potential of using neurophysiological responses to median nerve stimulation as neuroprognostic tool for unresponsive ICU patients.

Methods: Twenty-five healthy controls each completed one right and one left median nerve stimulation run during separate fMRI and fNIRS sessions on different days. The session order was counterbalanced across participants. Following validation, the protocol is being applied to behaviorally unresponsive ICU patients. Results from three patients are presented as a proof of concept.

Results: In healthy controls, fMRI detected activity for both hands in all individuals, while fNIRS detected responses in 23/25 (left hand) and 20/25 (right hand). At the individual ROI level, fMRI showed consistent activation in primary and contralateral secondary somatosensory cortices (100% - 96%), while fNIRS exhibited lower sensitivity (72% - 44%). In ICU cases, one patient exhibited strong neural responses across multiple ROIs, another showed weak but detectable activation, and a third showed no measurable response.

Conclusions: Healthy control findings suggest that while fNIRS has lower sensitivity than fMRI, it can still detect neural responses to median nerve stimulation. Preliminary patient results indicate that fNIRS has the potential to serve as a practical bedside assessment tool for unresponsive ICU patients who cannot undergo fMRI. Ongoing data collection will further evaluate its neuroprognostic value and optimize its clinical applications in critical care settings.

FLARES - fNIRS Lightweight Analysis Research and Evaluation Suite

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Abstract: We have developed FLARES (fNIRS Lightweight Analysis Research and Evaluation Suite) which is an application designed for customizable fNIRS analysis without previous coding knowledge. The application involves a 15-step process to convert and analyze data with over 60 customizable parameters available, which allows researchers to perform analysis of data in a quick and easy manner. The resulting data from the analysis is available in both text-based output for use in other external applications for more in-depth applications, or interactive two-dimensional and three-dimensional images to provide insights visually.

Introduction:
Processing functional near infrared spectroscopy (fNIRS) data is complex, involving knowledge of not only the fNIRS system but also an understanding of computer coding. The processing steps vary widely between groups, leading to a generalizability and reproduction crisis in the field [1]. Further, when using naturalistic tasks, the readily available programs typically use a canonical hemodynamic response function (HRF) which is not ideal for naturalistic behavioural coding [2]. There currently is no software application that provides researchers an easy way to perform this type of study, without prior coding knowledge. Using Python, existing libraries, and code modules created for the language, our pipeline was created to facilitate a quick, easy to use single application that does all the required processing of collected fNIRS data into meaningful results.

Methods: The pipeline created was written in the Python language and currently has 15 distinct steps that will transform an input file into data that can be visualized. The overview of these steps include loading a file into system memory, applying updated optode positions, temporal derivative distribution repair [3], wavelet filtering [4], calculating the participants heart rate from their data [5], scalp coupling index filtering [6], peak spectral power filtering [7], signal to noise ratio filtering [8], excluding channels (passageway between a source optode and a detector optode) marked as bad from the filtering, converting NIRS raw data to optical density [9], applying short channel regression (if present), calculating the hemoglobin concentration, creating a design matrix, running a general linear model, and finally extracting channel, region of interest, and contrast level effects out of the general linear model.

Results:
The FLARES application, as demonstrated in Figure 1, has many advantages due to the amount of customizability available. Further, this pipeline offers both the HRF and FIR models, increasing the potential to utilize this pipeline for more studies because the user can specify what type of response they want to better suit their study, along with the other 60 parameters that they can tailor to their needs.

Figure 1. A) A clip of the GUI interface for FLARES; B) an example of a cortical contrast image produced; C) an example of the GLM results for participants on a 2D optode array, with color representing the beta values and line parcellation representing significance.

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Localizing fNIRS hemodynamic oscillations on the cortical surface using wavelet MEM

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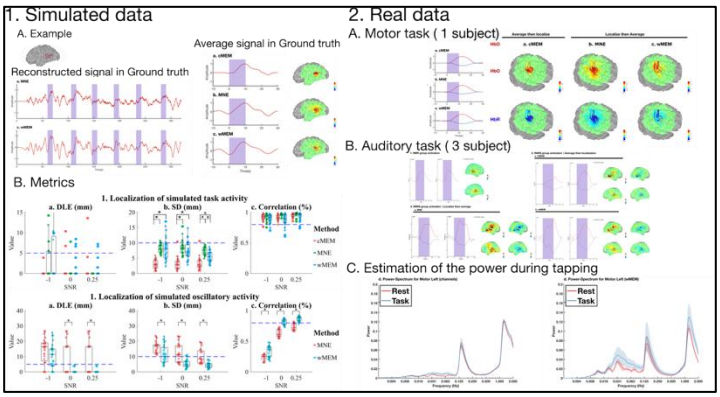
Abstract: Estimation of the hemodynamic fluctuation on the cortical surface is an ill-posed problem that requires validation. wavelet Maximum Entropy on the Mean (wMEM) is a method that has recently been validated for the localization of magnetoencephalography resting-state activity. In this work, we adapted wMEM for the localization of fNIRS resting state activity, validating it using controlled simulation and using real data.

Introduction: Hemodynamic signal measured by fNIRS or fMRI has been shown to display physiological fluctuations with specific frequency bands associated with specific physiological processes such as cardiac (0.8 - 1.5Hz), respiration (0.16 - 0.6Hz), low-frequency oscillations (0.04 - 0.15 Hz), and very low-frequency oscillations (0.01 – 0.04Hz) (Rojas et al, 2017). These oscillations have been proven to have associations with specific cognitive processes and to fluctuate during sleep (Ren et al, 2020). Therefore, we aim to answer how to reconstruct the spontaneous or evoked fNIRS oscillation on the cortical surface. For that, we adopted a method developed by our group, wavelet Maximum Entropy on the Mean (wMEM), recently validated for the reconstruction of resting state data of EEG/MEG, which takes advantage of discrete wavelet representation of the fNIRS signals to reconstruct resting state oscillations on the cortical surface at specific frequencies (Afnan et al, 2023). **Methods:** We evaluated wMEM against two methods: Minimum Norn Energy (MNE) and coherent Maximum Entropy on the Mean (cMEM) using both simulated data and real data. (1) For simulation, we extracted 22 minutes of awake rest data showing no major motion artifacts, applying the standard preprocessing pipeline. We simulated either a task or transient oscillations at 0.1 Hz for different regions spanning across the temporal lobes while mixing with realistic noise (resting state data) at different levels of SNR. After reconstructing the oscillation on the cortex using wMEM, we evaluated the reconstruction using several metrics based on the spatial accuracy of the reconstruction (Distance Localization Error – DLE, and Spatial Dispersion - SD) and temporal accuracy (temporal correlation). (2) To apply our method to real data, we first tried to estimate the hemodynamic response to two tasks: a finger tapping, and an auditory task. For that, we reconstructed the entire signal using wMEM and estimated the response by averaging the tapping trials. We compared that with the response estimated using MNE. We also compared our method to the standard approach consisting of averaging the trial first before doing the reconstruction on the cortex using cMEM (Figure 2.A, 2.B). (3) We then evaluated the performance of wMEM to reconstruct resting state data on the cortical surface. For that the time-frequency representation of the signal for each vertex of the middle temporal gyrus (Figure 2.A) was obtained using Morse continuous wavelets. We then estimated the average power spectrum over time during the tapping and rest periods. Using a similar method, we estimated the power spectrum for each channel (Figure 2.C).



Results: (1) On simulation, wMEM could reliably reconstruct the hemodynamic both task and oscillations on the cortical surface (Figure 1). (2) wMEM was able to accurately recover the response to the tasks: in the motor region for the tapping task, and in the auditory cortex for the auditory task. (3) We found that estimating the power spectrum on the cortical surface was able to better disentangle between the task and the rest period, with larger power in the task in the frequency band of 0.03Hz (Figure 2.C).

Conclusion: This study demonstrates the application of wMEM for reconstructing hemodynamic oscillations on the cortical surface.

Brain functional connectivity and growth measurements in near-term and term-born neonates: an fNIRS study

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Abstract: Resting-state networks (RSNs), measurable at birth using functional connectivity (FC), are linked to developmental outcomes. Intrauterine growth influences neonatal anthropometric measurements (AMs) such as birthweight, crown-heel length and head circumference, which are related to brain structure and connectivity. This study examined the relationship between AMs and FC in 121 neonates (67 males, 12 small for gestational age, 13 large for gestational age). Using functional Near-Infrared Spectroscopy and linear modelling, we found nonlinear associations: birthweight and Ponderal Index showed negative quadratic relationships with FC, while head circumference showed positive quadratic relationships. Findings underscore growth-related influences on early brain networks.

Introduction: Resting-state networks (RSNs), measured by functional connectivity (FC), emerge *in utero* and are observable at birth. The early organization of RSNs has been linked to later neurodevelopmental outcomes. Neonatal growth, reflected in anthropometric measures (birth weight, length and head circumference), is also associated with variations in brain structure and connectivity. Yet, the normative relationship between growth at birth and FC patterns of RSNs has not been clearly established. We therefore examined how neonatal growth influences RSN connectivity in healthy newborns.

Methods: Functional Near-Infrared Spectroscopy was used to record task-free data and FC was calculated in 121 neonates (67 males, 12 small for gestational age infants, 13 large for gestational age infants, mean postnatal age = 25.6 hours, SD = 13.89, mean gestational age = 38.63 weeks, SD = 1.39, mean birth weight = 3211.21g, SD = 618.46, mean head circumference = 34.67 cm, SD = 2.50, mean length = 49.69 cm, SD = 3.62). We utilized a generalized linear model and linear mixed effects models to understand the relationship between FC and AMs, including birth-weight for gestational-age z-score (BGZ), head-circumference for gestational-age z-score (HGZ), birth-weight for length z-score (BLZ) and the Ponderal Index (PI).

Results: Channel-wise comparative analysis demonstrated that BGZ (β range = -0.102 to -0.074, FDR-corrected $p < 0.005$) and the PI (β range = -0.088 to -0.074, FDR-corrected $p < 0.001$) have negative quadratic relationships with several inter- and intrahemispheric channel pairings. HGZ demonstrated positive quadratic relationships with several channel pairings (β range = 0.051 to 0.074, FDR-corrected $p < 0.001$).

Conclusion: These findings indicate that AMs are non-linearly associated with resting-state FC across several channels in the first days of life. The present study highlights the importance of considerations for early growth and brain network organization when studying early development.

Paradoxical Cortical fNIRS Responses to Electromagnetic Induced Magnetophosphene Perception

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Abstract: Transcranial Alternating Magnetic Stimulation (TAMS)—a novel non-invasive brain stimulation technique—is known to evoke visual percepts referred to as magnetophosphenes. This study investigated the cortical hemodynamic responses to TAMS using functional near-infrared spectroscopy (fNIRS). Stimulation was applied tangentially to the external side of the eye, centered over the eyeball, in healthy adult participants while fNIRS signals were recorded from occipital regions. Changes in oxygenated and deoxygenated hemoglobin concentrations were analyzed relative to stimulation epochs. Results revealed a paradoxical decrease in visual cortex activation concurrent with magnetophosphene perception.

Introduction: Magnetophosphenes—illusory light percepts induced by time-varying magnetic fields—offer a unique means to probe how magnetically induced electric fields influence cortical excitability[1,2]. Although the retinal mechanisms underlying these percepts are relatively well characterized, their cortical correlates remain poorly understood[1,2]. In this study, we investigate, for the first time, cortical responses to a novel stimulation approach, *transcranial alternating magnetic stimulation* (TAMS)[1,2] applied over the eye, to map visual cortex activation associated with magnetophosphene perception. Functional near-infrared spectroscopy (fNIRS) was used to detect subtle hemodynamic changes that reflect cortical involvement during stimulation.

Methods: Four healthy adult participants underwent TAMS stimulation with the center of the coil positioned tangentially to the external side of the eye, centered over the eyeball. Stimulation was delivered at 20 Hz with a flux density of 100 mT_{rms}, parameters known to reliably elicit magnetophosphene perception. Functional near-infrared spectroscopy (fNIRS) optodes (8 sources and 7 detectors, with 8 short channels) were placed bilaterally over the occipital cortex to monitor hemodynamic changes in oxygenated and deoxygenated hemoglobin concentrations. A block design with 6 alternating blocks of 20 seconds of stimulation and 25 seconds of rest was used to elicit brain activity. The raw changes in light intensity were converted to changes in oxy- and deoxyhemoglobin, corrected for motion artifacts, and band-pass filtered (between 0.01 and 0.5 Hz) to remove high frequency noise. Short channels were then regressed to remove systemic physiological noise, and GLM analysis was conducted with a contrast of task > rest to investigate the brain areas activated during the task.

Results: Consistent across all four participants, a decrease in oxyhemoglobin was observed in the visual cortex. Simultaneously, an increase in deoxyhemoglobin concentration was observed for some channels during the task, suggesting an inverted response (Fig1). These results did not survive FDR correction for multiple comparisons.

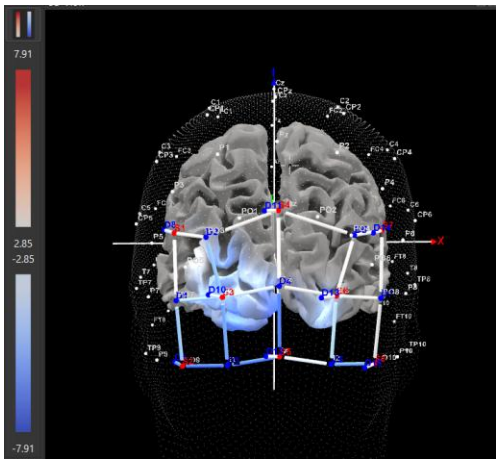

Figure 1: 3D visualization of cortical deactivation for a representative participant. The image shows deactivation over occipital regions, illustrating the typical group pattern. Optode positions from the 10–20 system are overlaid on

a brain model, with color mapping representing t-values (–7.91 to +7.91), where negative t-values (blue) indicate deactivation and positive t-values (red) indicate activation.

Discussion and conclusion: The inverted responses (commonly known as deactivation) during the task are rather ambiguous and counterintuitive to what is expected. A larger study will be conducted to gain a deeper understanding of this phenomenon. An MRI-compatible, full-head system will also be used to place optodes directly under the stimulation site, allowing for a more precise investigation of full brain hemodynamics during stimulation.

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Examining Real-World Cognition in Healthy Aging and Alzheimer's Disease Using Movies and Functional Near-Infrared Spectroscopy

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Abstract: Traditional neuroimaging and cognitive assessments have advanced understanding of aging and Alzheimer's disease (AD), yet they often fail to capture cognition as it unfolds in real-world contexts. The present research employed functional near-infrared spectroscopy (fNIRS) with naturalistic movie paradigms to investigate higher-order cognitive processing in healthy aging and AD. As predicted, healthy older adults demonstrated robust neural synchronization in frontoparietal regions during coherent narratives, whereas patients with AD exhibited marked reductions across sensory and associative cortices. These results highlight the value of naturalistic fNIRS paradigms for detecting age- and disease-related differences in ecologically valid cognition.

Introduction: Normal aging and AD are associated with declines in memory, attention, and executive function, yet standardized tasks may not reflect how cognition operates in everyday contexts. Naturalistic paradigms, such as movie viewing, provide dynamic, engaging stimuli that capture complex, integrative processes. This research aimed to validate a naturalistic fNIRS paradigm for measuring higher-order cognition in normal aging and apply it to AD to assess disease-related impairments in real-world cognitive function.

Method: Cognitively healthy younger adults (n = 26), older adults (n = 26), and patients with AD (n = 15) were presented with coherent and scrambled movie narratives while fNIRS recorded cortical hemodynamic responses. Inter-subject correlations (ISCs) were calculated to measure neural synchronization across participants, focusing on frontoparietal and temporal regions implicated in attention, memory, and narrative processing. Subjective engagement was indexed using suspense ratings.

Findings: Both younger and older adults showed widespread ISCs during coherent movies, engaging the prefrontal, lateral temporal, and temporoparietal cortices associated with higher-order cognition. Synchronization in these regions correlated with narrative suspense, confirming meaningful engagement. Although older adults exhibited modest reductions in ISCs, particularly in sensory and attentional regions, they maintained substantial overlap (73% for *BYD*, 48% for *Taken*) with younger adults, indicating preserved narrative comprehension. In contrast, patients with AD displayed significantly reduced within-group ISCs across all conditions, with residual synchronization restricted to lower-level sensory areas. Despite absent within-group synchrony, cross-group ISCs showed that patients with AD aligned with healthy older adults in frontal and parietal regions, likely reflecting islands of preserved processing that vary across individuals due to disease-related heterogeneity.

Interpretation: These findings demonstrate that while normal aging dampens neural synchrony, higher-order processing remains largely intact. In AD, however, reduced synchrony across sensory and associative cortices reflects a loss of integrative network function consistent with the disease's "disconnection" profile. Importantly, naturalistic fNIRS paradigms captured these nuanced differences, offering a portable and ecologically valid means to assess real-world cognition in aging and neurodegenerative populations. This approach may serve as a sensitive tool for detecting, monitoring, and understanding cognitive decline across the lifespan.

Movement or Medication in ADHD: Interaction Between Medication and Physical Activity on Neurocognitive Functioning

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Background/Objectives: This study investigated the effect of movement during executive functioning on dorsolateral prefrontal cortical (DLPFC) activity and inhibitory control, with a focus on the influence of medication status. **Methods**: Twenty-six children with ADHD (15 medicated; 11 unmedicated) and 24 children without ADHD completed a Stroop task while remaining stationary and while desk cycling. Functional near-infrared spectroscopy (fNIRS) recorded oxygenated and deoxygenated changes in hemoglobin within the left DLPFC. **Results**: Sixty-four percent of unmedicated children with ADHD showed greater left DLPFC activity while desk-cycling, compared to 47% of medicated children. Unmedicated children also showed higher accuracy scores while desk-cycling, while medicated and control groups did not differ by condition. **Conclusions**: Medicated ADHD children did not benefit from movement during executive functioning, whereas unmedicated ADHD children showed significantly greater DLPFC activation and inhibitory control when engaging in movement.

Feasibility of Using Hybrid NIRS/DCS to Measure Changes in Cerebral Blood Flow and Volume Pulsatility

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Abstract: The shape of cerebral pulsatile waveforms can serve as a potential biomarker of cerebrovascular health. Therefore, we assessed the feasibility of using a hybrid trNIRS/mdDCS system to measure microvascular cerebral blood flow and volume waveform morphology during posture-induced intracranial pressure changes. Significant differences in microvascular waveform morphologies were found between supine and standing postures, which aligned with the observed macrovascular changes.

Introduction: The cerebral blood flow waveform carries rich information about cerebrovascular health as its shape changes with blood pressure, vascular resistance and intracranial pressure.[1] Consequently, this waveform can serve as a potential biomarker of brain injury and pathologies. The aim of this work was to assess the feasibility of using an in-house built optical system (Figure 1a) that combines time-resolved near-infrared spectroscopy (trNIRS) with multi-distance diffuse correlation spectroscopy (mdDCS) to measure pulsatile components related to cerebral blood volume and flow, respectively.[2] The ability of the hybrid system to detect changes in the waveform morphology was assessed by inducing intracranial pressure changes through a change in posture (i.e., supine and standing).

Methods: Data acquisitions were collected during standing and supine postures in 10 healthy adults (30 ± years, 5 female). mdDCS blood flow index (BFi) was measured at two source-detector distances: 0.7 cm to measure scalp and 2.8 cm to measure the brain. The total hemoglobin waveform (HbT) measured by trNIRS at 4 cm was used as a surrogate of blood volume. Both systems acquired data at 20 Hz. For comparison, transcranial Doppler ultrasound (TCD) was used to measure middle cerebral artery blood velocity (MCAv). Posture-related differences in pulse amplitude (systolic peak - diastolic nadir) were compared using a paired t-test.

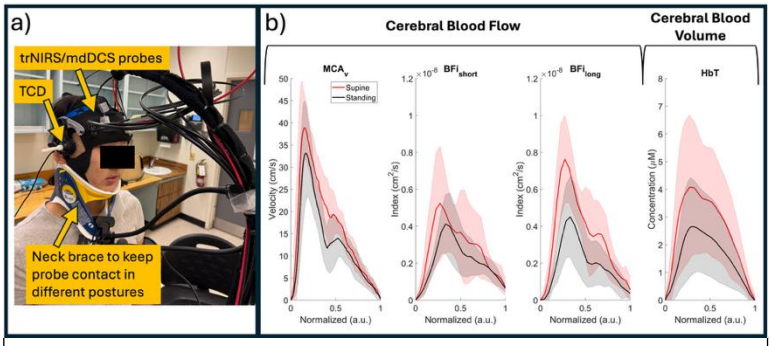

Figure 1: a) Experimental setup. b) Cerebral blood flow and volume pulsatility

Results:
Pulse amplitude was significantly different between postures for macrovascular blood flow (MCAv; $p < 0.05$), microvascular blood flow (BFi_{long}; $p < 0.005$), and blood volume (HbT; $p < 0.01$; Figure 1b). BFi at 0.7 cm, which captures scalp blood flow did not show a significant difference between postures (BFi_{short}; $p = 0.09$; Figure 1b).

Conclusions: These preliminary data demonstrate the feasibility of using a hybrid optical system to capture multiple components of flow pulsatility in the human brain. The BFi waveform reflects the blood flow pulse at the smallest arteriole branches prior to the capillary bed, while the HbT waveform represents the combination of microvascular arterial and venous blood volumes, which is influenced by intracranial pressure. The relationship between these waveforms and the macrovascular waveform measured by TCD is likely altered by factors such as hypertension.

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Predicting Neurological Recovery in Acutely Brain-Injured Patients using Functional Near-Infrared Spectroscopy

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Abstract: Accurate prognostication in unresponsive, acutely brain-injured patients remains difficult. While EEG and fMRI can detect preserved brain activity, their use in the ICU is limited. Functional near-infrared spectroscopy (fNIRS) provides a portable, bedside alternative by measuring cortical hemodynamics. In 33 ICU patients, fNIRS connectivity features trained a machine learning model to predict six-month outcomes (Glasgow Outcome Scale-Extended). The model achieved 81.3% balanced accuracy, outperforming behavioural and clinical predictors, and predicted later behavioural recovery but not covert awareness. These findings support fNIRS as a scalable tool for enhancing prognostication in critically ill patients.

Introduction: Accurate and early prognostication in unresponsive acutely brain-injured patients remains a major clinical challenge. Functional neuroimaging techniques such as electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) have shown increasing promise for predicting neurological recovery by detecting preserved brain activity that may not be evident through bedside examination. However, their adoption in the intensive care unit (ICU) remains limited by cost, clinical inertia, and the need for stronger evidence supporting their value. fNIRS offers a scalable alternative, combining the bedside convenience of EEG with the ability to assess cortical hemodynamics in patients who are often too unstable for fMRI.

Method: Thirty-three acutely brain-injured ICU patients underwent fNIRS recording while listening to two engaging audio-only movie clips. Functional connectivity features were used to train a machine learning model to classify six-month neurological outcomes using the sing the Glasgow Outcome Scale-Extended (GOSE) as favourable (GOSE > 4) or unfavourable (GOSE <4). Model performance was compared with validated behavioural assessments and clinical variables. The model was also retrained to predict two secondary outcomes: (1) behavioural responsiveness, defined as observable command-following any time after testing, and (2) neural command-following (covert awareness), defined as brain-based evidence of command-following at the time of testing.

Findings: Twenty-six patients had an unfavourable outcome and seven had a favourable outcome. The fNIRS-based model predicted six-month outcomes with 81.3% balanced accuracy (sensitivity = 85.7%, specificity = 76.9%; p = .006), outperforming models based on behavioural and clinical measures (67.6% balanced accuracy; p = .018). When retrained on secondary outcomes, the model predicted recovery of behavioural responsiveness with 78.3% balanced accuracy (p = .012) but did not significantly predict covert awareness (balanced accuracy = 70.4%, p = .109).

Interpretation: fNIRS-based models predicted long-term functional outcome and recovery of behavioural responsiveness in acutely brain-injured ICU patients. This bedside-compatible tool may enhance prognostication by providing objective neural information that complements behavioural assessment.

Influence of Vibratory Plantar Stimulation on Cortical Motor Planning and Spatiotemporal Step Parameters

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Abstract: During gait, plantar mechanoreception informs anticipatory postural adjustments and foot placement; augmenting this feedback via vibratory insoles may stabilize gait, yet its effect on cortical motor planning is unclear. We tested whether augmenting plantar mechanoreception alters premotor cortex (PMC) planning activity and relates to step width variability (SWV) during gait initiation. Healthy young adults (N=32) performed single-step initiation tasks in a contingent negative variation-style paradigm while PMC activity was recorded via fNIRS and lower-limb kinematics via inertial measurement units. Planning a step increased left PMC activity compared to rest. Neither step type nor vibration affected PMC activity. PMC-SWV correlations were non-significant.

Introduction: Plantar mechanoreception contributes to anticipatory postural adjustments and precise foot placement during gait. Given that gait initiation engages cortical motor planning processes, particularly within the PMC, the present study examined whether augmenting foot-sole feedback via vibratory insoles modulates PMC planning activity, and whether this neural signal relates to lateral stability indexed by step width variability. Heel- versus toe-strike planning was contrasted to probe task-dependent motor planning demands, with the additional hypothesis that vibration could differentially influence these processes in healthy young adults.

Methods: A within-subjects design was implemented with participants performing single-step initiations in a contingent negative variation-style paradigm, planning either heel- or toe-first steps. Vibratory insoles (ON/OFF; counterbalanced) augmented plantar feedback across blocks. PMC activity was measure via functional Near-Infrared Spectroscopy, and lower-limb kinematics were recorded via inertial measurement units. fNIRS data were analyzed with a general linear model; differences in task-related activation were tested using two-way repeated-measures ANOVA, and PMC-SWV associations were assessed using nonparametric correlation.

Results: Thirty-two (N=32; 18 female) healthy young adults with mean age 24±4.4 were included in the data analysis. Planning a step increased left PMC activation relative to rest ($p = 0.007$), indicating cortical engagement during the planning phase prior to gait initiation. No differences in PMC planning activity were observed between step types ($p = 0.485$), and vibratory augmentation did not have an effect of PMC planning responses ($p = 0.887$). Left PMC planning activation did not correlate with SWV. Collectively, the findings suggest that acute augmentation of plantar mechanoreception does not alter PMC planning activation, nor predict SWV in a single-step gait initiation task.

Conclusions: The findings of the present study indicate that planning to initiate gait engages the PMC prior to the onset of movement. However, acute augmentation of plantar mechanoreception via vibratory insoles does not alter PMC planning activity. Furthermore, PMC planning activity did not correlate with step width variability. Taken together, these results suggest that augmenting plantar mechanoreception via vibratory insoles has limited effects on PMC planning responses and SWV for a single-step initiation task in healthy young adults. Future work should examine other cortical motor regions under different stimulation protocols, tasks, and populations.

Characterizing Cortical Responses during Performance of KINARM Sensorimotor Tasks using fNIRS in Healthy Young Adults

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Abstract: The KINARM robot is a gold-standard tool for assessing sensorimotor function, but it has rarely been paired with neuroimaging. This study combines KINARM tasks with functional near-infrared spectroscopy (fNIRS) to examine cortical responses in healthy participants. While wearing an fNIRS cap, participants complete Object Hit, Object Hit & Avoid, Visually Guided Reaching, and Reverse Reaching tasks. Preliminary results reveal distinct hemodynamic activity, including contralateral motor cortex activation during reaching, and prefrontal engagement during decision-heavy tasks. This novel KINARM–fNIRS approach may inform personalized rehabilitation and establish baselines for detecting early sensorimotor deficits.

Introduction: The KINARM robot is widely used to assess sensorimotor function but has rarely been paired with neuroimaging.[1, 4] Functional near-infrared spectroscopy (fNIRS) provides a non-invasive method to study cortical activity during motor performance.[2-3] Combining these tools may advance understanding of the neural mechanisms underlying sensorimotor control.

Methods: Healthy participants wore an fNIRS cap while completing four KINARM tasks: Object Hit, Object Hit & Avoid, Visually Guided Reaching, and Reverse Reaching. Hemodynamic responses in prefrontal and motor cortices were analyzed using correlation matrix.

Results: Preliminary findings (n=15) reveal distinct cortical activation patterns. Stronger functional connectivity between regions was observed in more decision-heavy tasks (Reverse Visually Guided Reaching, Object Hit & Avoid) compared to simpler reaching tasks. Contralateral motor cortex activation was particularly evident during precise reaching movements.

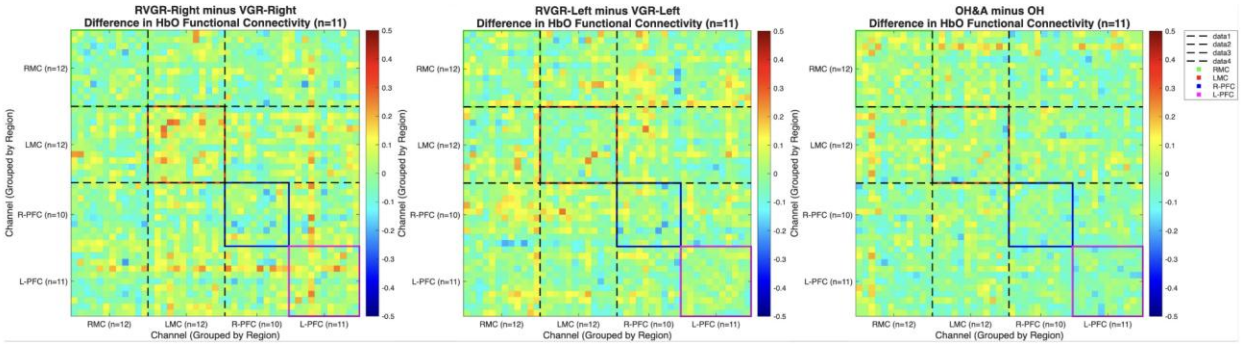

Figure 1: Differential correlation matrices for each cognitively demanding KINARM task relative to its less demanding counterpart. Subtracting baseline (less cognitive) tasks highlights residual connectivity patterns, revealing cortical regions more engaged during cognitively heavier activity.

Conclusions: The integration of KINARM and fNIRS reveals task-dependent cortical responses, with heightened prefrontal involvement during decision-making demands. Establishing these neural signatures in healthy participants provides a foundation for future work aimed at detecting sensorimotor deficits and informing personalized rehabilitation strategies.

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A Sensometric Study of Chocolate Preference Combining Neuroimaging and Olfactometry

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Abstract: Food preferences are complex, with both biological and social underpinnings. Various brain regions, such as the prefrontal cortex and hypothalamus, are implicated in food preferences and eating behaviour via mechanisms related to sensory perception, appetite, and cognitive function. This study sought to examine links between neural and sensory attributes with chocolate preference, to provide an experimental protocol to investigate complex contributors to food preferences. Initial findings from 10 participants (3 males, 7 females) aged 18-45 years are included in this preliminary analysis.

Introduction: To explore the complexity underlying food preferences, this study examined links between exposure to chocolate aroma and neural activity in the prefrontal cortex (PFC), and whether they differed according to chocolate preference. We hypothesized that PFC activity would differ between chocolate likers (CL) and neutral/dislikers (ND) during exposure to chocolate aroma vs. neutral air.

Methods: Participants self-reported their chocolate preference (liking vs. disliking) on a 9-point Likert scale, and their height (m) and weight (kg) were measured to calculate body mass index (BMI). A functional near-infrared spectroscopy (fNIRS) cap measured PFC activity during the experiment (22 channels). Chocolate aroma or neutral air was presented in a pseudorandomized fashion using an olfactometer. Instructions for "smell" (10 seconds) and "rest" (15 seconds) periods were displayed on a screen, totaling to 32 "smell" periods: 16 chocolate and 16 neutral air. General linear models analyzed oxyhemoglobin (HbO) response in each fNIRS channel for the neutral air and chocolate aroma conditions. The beta coefficients obtained represented the amplitude of the changes in each experimental condition for every participant. These coefficients were used in a 2 (aroma condition: chocolate vs. neutral air) x 2 (chocolate preference: CL vs. ND) mixed-design analysis of variance adjusted for BMI.

Results: HbO was significantly lower in 1 channel in the left orbitofrontal area during chocolate aroma exposure compared to neutral air ($p=0.04$, $n=10$). CL had significantly lower HbO in 6 channels in the orbitofrontal and dorsolateral PFC areas on average during the experiment compared to ND (all $p<0.05$). No significant interaction was present between aroma condition and preference group.

Conclusions: Research that combines neuroimaging and olfactometry may help uncover neural signatures for food preferences.

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A longitudinal exploration of children's neural development and learning in a progressive laboratory school

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Abstract: Children show wide variation in learning outcomes despite similar learning environments. Neurocognitive development is a key contributor to learning, but few studies track its impact over time. We outline a longitudinal research protocol that explores how differences in brain function relate to academic and socioemotional growth from early to middle childhood. Set within a laboratory school of 200 children, the study uses neuroimaging, behavioral tasks, standardized assessments of children. Home and school learning environments are assessed through caregiver reports and classroom observations. By linking brain development to real-world educational experiences, we aim to deepen current understanding of how children learn.

Introduction: Children's learning outcomes vary widely, even among those in similar educational settings. A growing body of research highlights neurocognitive development as a key contributor to this variability (Levine, 2009), yet longitudinal studies that examine how individual differences in brain function relate to learning remain limited. This project aims to gain a deeper understanding of how variation in neurocognitive development shapes academic and socioemotional outcomes across early to middle childhood. Conducted within a progressive laboratory school, the study explores how children's learning unfolds in real-world environments, offering insight into the dynamic interplay between brain development, learning experiences, and educational growth.

Methods: This longitudinal study will aim to recruit 200 children aged 3 to 12 from the Dr. Eric Jackman Institute of Child Study. Information will be gathered from children, caregivers, and teachers. Children will participate in annual assessments over five years, including behavioral and neuroimaging measures. Specifically, functional near-infrared spectroscopy (fNIRS) will measure cortical activation during cognitive tasks. Primary outcomes include academic achievement in reading, math, and science, and socioemotional skills. Caregiver reports will capture the home learning environment, while classroom video-recordings will document instructional practices and social dynamics within the school. Figure 1 provides the procedural flow of the study. We hypothesize that individual variation in neurocognitive development will be associated with differences in learning outcomes, and that these associations will be shaped by the learning environments at home and in school.

Dissemination: We will inform parents and their children of the study procedure through hands-on demonstrations of the fNIRS brain imaging technology, where children can try on the gear, explore how it works, and see their brains "in action." This will be provided as part of the laboratory school's event for families, giving kids a fun activity and offering parents the opportunity to observe, ask questions, and learn more about the study. Children between ages 11 and 12 will further be invited to assist with data collection as junior research assistants and help interpret findings as part of a student advisory committee. Standardized measures of children's academic outcomes will be shared with parents in the form of handouts co-developed with educators at the laboratory school. Research findings will be shared through conference presentations, peer-reviewed journals, and open-access publications.

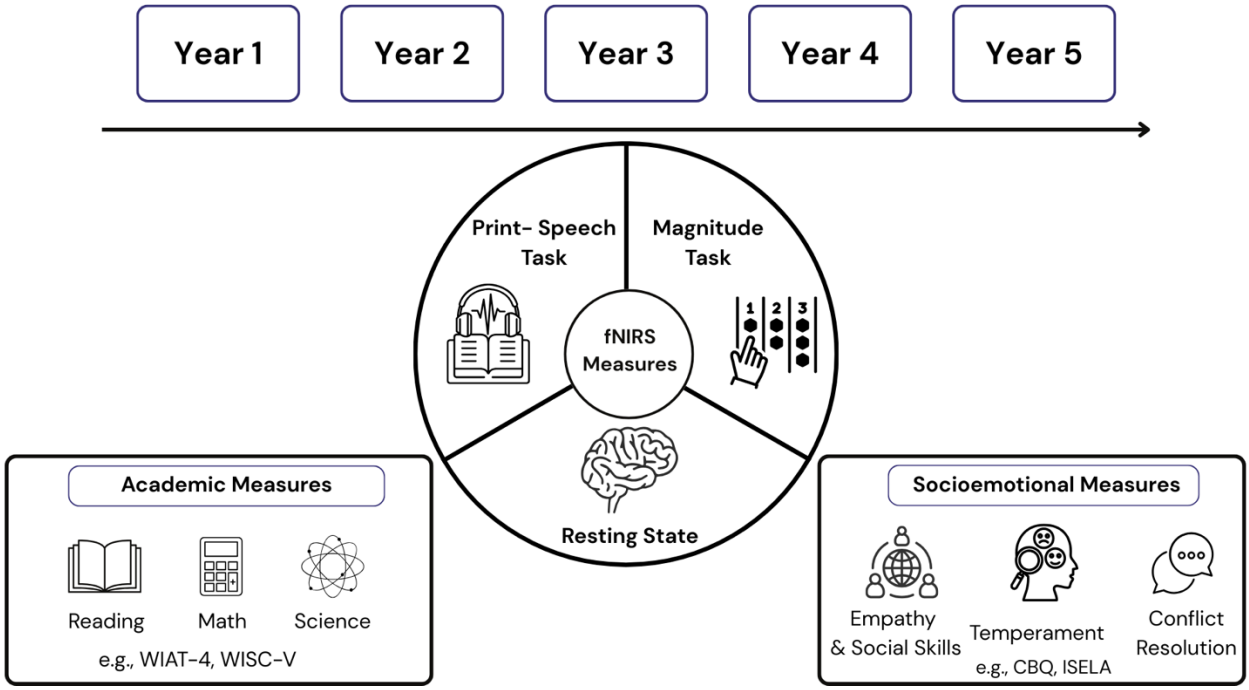

Figure 1: Flow diagram for study.

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Detecting Consciousness after Acute Brain Injury: A Simultaneous EEG-fNIRS approach

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Abstract: Functional neuroimaging has been used to detect covert consciousness in behaviorally unresponsive patients through imagery-based command-following tasks. fMRI, EEG, and fNIRS have each been applied in these paradigms, but all face distinct limitations in clinical viability. Simultaneous EEG–fNIRS offers complementary temporal and spatial resolution, with studies showing a 5–10% improvement in classification accuracy. We piloted a novel paradigm enabling concurrent acquisition of robust EEG signatures and fNIRS activation maps in healthy controls within a 16-minute protocol. This study aims to test the accuracy and feasibility of this rapid, multimodal approach for use in the ICU.

Introduction: Advances in functional neuroimaging have revealed that some behaviorally unresponsive patients retain covert consciousness detectable through imagery-based command-following tasks. While fMRI has demonstrated this reliably, its lack of portability limits clinical use. EEG and fNIRS are more accessible alternatives but face their own challenges, including reduced accuracy and prolonged testing times. Combining EEG and fNIRS simultaneously offers complementary strengths, including high temporal precision and the spatial mapping of cortical hemodynamics, all while maintaining bedside feasibility. Previous studies suggest such hybrid systems can increase classification accuracy by 5–10%, depending on task design and recording parameters. However, this approach has not yet been optimized for the intensive care environment, where portability, rapid setup, and high accuracy are essential. This study seeks to design and validate a simultaneous EEG–fNIRS protocol tailored for these clinical demands.

Methods: Participants will complete a rhythm-guided motor imagery task designed to elicit both electrophysiological and hemodynamic responses. Each trial begins with an instruction period followed by a brief beat-training sequence, after which participants are cued to imagine knocking with their right hand in synchrony with the beat. Trials are structured for simultaneous acquisition, with extended blocks optimized for fNIRS and shorter, beat-synchronized epochs aligned for EEG analysis. The protocol includes 24 fNIRS trials and 240 EEG epochs across conditions. Data will be collected using a prepopulated fNIRS cap integrated with custom-designed wet-electrode grommets, enabling rapid EEG setup. fNIRS features (HbO, HbR, HbT) and EEG features spanning both spectral (event-related de/synchronization, coherence, frequency–phase coupling) and temporal domains (steady-state responses) will be extracted for classification of motor imagery versus rest. By capturing spatial, spectral, and temporal signatures of task-related activity, the approach is designed to maximize the information available to various classifiers. Classifier performance will be evaluated using ROC-based AUC analysis to optimize sensitivity and specificity.

Prediction and Application: We predict that this protocol will yield reliable multimodal markers of motor imagery within short testing sessions. Based on prior findings, classification accuracy is expected to exceed fNIRS-only performance by 5–10%, reaching approximately 85–90%. If successful, the approach could facilitate rapid bedside detection of covert consciousness in ICU patients and, in the longer term, lay the groundwork for communication paradigms that allow patients to participate in their own care decisions.

Long-term brain function alterations following early childhood malnutrition during a Go-No-Go task

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Abstract (max 100 words): Childhood malnutrition is a major global health challenge, with long-term consequences on cognition and mental health. Yet, its long-term effects on brain function remain poorly understood. This study examined whether early malnutrition is associated with altered brain activation in adulthood as measured by NIRS during attention and inhibition engagement. Results revealed alterations in brain function in frontal and temporal regions in previously malnourished adults compared to controls, suggesting a potential compensation mechanism. This study underscores the long-term neurodevelopmental impact of childhood malnutrition and the need for early interventions.

Introduction: Malnutrition arises when nutrient intake fails to meet the body's functional requirements (Bhutta et al., 2017; Galler et al., 2021), leading to lasting adverse effects on cognition, behavior and mental health, inevitably hampering well-being and productivity in adulthood (Kirolos et al., 2022). One key pathway linking early malnutrition to impaired cognitive and mental functions is through alterations in brain development. Because infancy is marked by rapid neural growth, nutritional deprivation during this period may result in long-lasting changes in brain structure and function. Understanding its long-term impact on the brain is therefore critical for guiding interventions and follow-up care.

Methods: Fifty-five adults from the Barbados Nutrition Study cohort, who experienced moderate-to-severe malnutrition restricted to the first year of life and matched controls, performed a Go-No-Go task while brain activity was recorded with near-infrared spectroscopy (NIRS). The NIRS data were preprocessed according to established guidelines using the LIONirs toolbox, and the task-related hemodynamic response was extracted using a General Linear Model approach. Statistical analyses employed linear mixed models to examine associations between early malnutrition and ROI averaged brain activation, while controlling for childhood socioeconomic status.

Results: Early malnutrition was associated with altered hemodynamic responses in the right frontal-posterior and left temporal regions (see Figure 1). These associations suggest compensatory hyperactivation in task-relevant frontal areas alongside reduced recruitment of left temporal regions, consistent with a redistribution of neural resources.

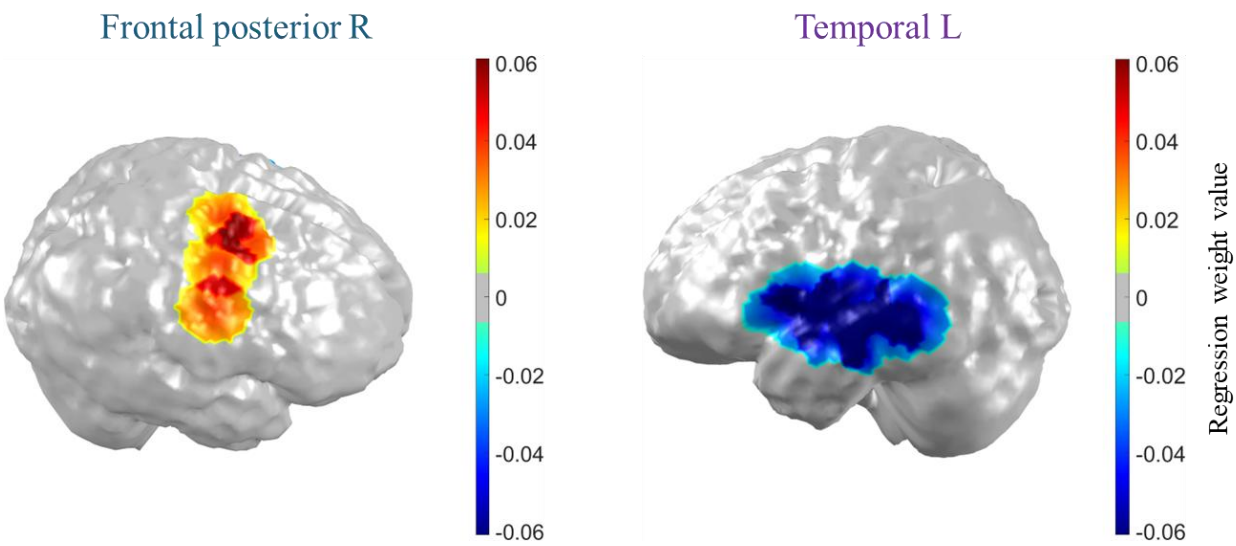

Figure 1: Topological representation of the significant LMM Group effects.

Conclusions: Our findings highlight persistent alterations in adult brain function following early malnutrition and identify frontal and temporal regions as potential functional biomarkers. They provide support to the 'frontal fragility' hypothesis we have previously advanced (Roger et al., 2024). This work represents one of the rare investigations of adult brain function following infant malnutrition and underscores the importance of considering long-term consequences on neurodevelopment in global health efforts.

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Functional Connectivity and Machine Learning Classification of Neonatal Brain Injury Using fNIRS

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Abstract: Functional near-infrared spectroscopy (fNIRS) enables non-invasive measurement of resting-state functional connectivity (RSFC) in neonates, offering insights into early neural network development and brain injury. This study aimed to investigate group-level connectivity patterns in healthy newborns and those with hypoxic-ischemic encephalopathy (HIE) or intraventricular hemorrhage (IVH), and to explore the potential of machine learning in classifying injury severity. Data were collected from 117 healthy infants, 51 with HIE, and 30 with IVH. Following signal quality and channel-exclusion criteria, 73 healthy, 25 HIE, and 18 IVH datasets were included in the analysis. Oxygenated hemoglobin (HbT) Z-transformed correlation coefficients were used to estimate RSFC. Both HIE and IVH groups demonstrated increased overall connectivity compared to healthy infants, consistent with prior literature suggesting impaired autoregulation and immature neurovascular coupling. An initial Support Vector Machine (SVM) classifier trained on ~190 HbT-derived connectivity features per subject achieved an accuracy of 43.1% and a macro F1-score of 0.39, with the highest precision for the healthy group. These preliminary findings highlight the promise of integrating fNIRS-derived connectivity features with machine learning to advance early detection of neonatal brain injury.

Introduction: Early detection of brain injury in neonates remains a clinical challenge. Functional near-infrared spectroscopy (fNIRS) offers a portable and non-invasive method to assess resting-state functional connectivity (RSFC), reflecting the coordination of spontaneous neural activity. Previous research has demonstrated altered connectivity patterns in infants with hypoxic-ischemic encephalopathy (HIE) and intraventricular hemorrhage (IVH). However, group-level differences in connectivity and their potential for machine learning-based classification remain understudied. This study investigates RSFC differences across healthy, HIE, and IVH neonates and explores whether fNIRS-derived connectivity features can support classification of brain injury severity.

Methods: Resting-state fNIRS data were collected from 117 healthy neonates, 51 with HIE, and 30 with IVH. Following preprocessing including motion correction, filtering, and signal quality checks (SCI > 0.7, PSP > 0.1) 73 healthy, 25 HIE, and 18 IVH datasets were retained. HbT correlation matrices were generated and Z-transformed to assess RSFC. Group-level connectivity differences were examined using summary connectivity metrics. For classification, a Support Vector Machine (SVM) model was trained on ~190 HbT Z-values per subject, using five-fold cross-validation to evaluate model performance.

Results: The HIE and IVH groups showed higher total HbT connectivity relative to healthy neonates, **consistent with prior literature** describing elevated RSFC in the presence of disrupted autoregulatory and neurovascular mechanisms. The SVM classifier achieved a macro F1-score of 0.39 and an overall accuracy of 43.1%, with the best classification performance for the healthy group. These results suggest distinct RSFC signatures between healthy and injured neonates, though model refinement is needed to improve discrimination between injury types.

Conclusion: This study demonstrates that fNIRS-derived resting-state connectivity patterns differ between healthy neonates and those with HIE or IVH. Early machine learning models using these connectivity features show potential for classifying neonatal brain injury. Ongoing work will focus on parameter optimization, feature selection, and interpretability to enhance clinical utility for early detection and monitoring of brain injury in newborns.

Altered Resting State Networks in Neonates With Severe Hypoxic Ischemic Encephalopathy: A fNIRS Study

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Abstract: Neonatal hypoxic-ischemic encephalopathy (HIE) is a leading cause of cognitive and behavioral impairments. Bedside assessment of functional brain connectivity may facilitate early diagnosis and evaluate effectiveness of therapeutic hypothermia. We examined resting-state functional connectivity (rsFC) in 16 neonates with HIE (>35 weeks gestation) using Dual BabyBrite fNIRS between 5–15 days of life. Graph theory analysis revealed that lower first postnatal gas pH was associated with higher assortativity (r=-.64, p<.01) and lower hierarchy (r=.56, p<.05). These findings suggest that more severe HIE is associated with localized, hyperconnected resting state networks, reflecting altered network that may indicate risk of neurodevelopmental outcomes.

Introduction: Neonatal hypoxic-ischemic encephalopathy (HIE) is a perinatal brain injury, associated with cognitive delays, behavioral concerns, and learning disabilities in children. Bedside assessment of functional brain connectivity during the tertiary phase of injury may help understand the recovery process and effectiveness of therapeutic hypothermia. In this study, we aim to characterize the brain network topology and resting-state functional connectivity in neonatal HIE using fNIRS. We hypothesize that altered brain topology would be associated with severity of HIE, which may reflect adaptive mechanisms after brain injury.

Methods: Neonates >35 weeks gestation and birthweight >1800g with fetal acidosis and encephalopathy were enrolled. Resting-state brain activity was measured for 20 minutes using dual BabyBrite fNIRS (Artinis Medical Systems) between 5–15 days of life. Our cap had 54 channels, covering frontal, parietal, occipital, and bilateral temporal lobes. We used Homer3 and NIRS_KIT for preprocessing the data and GRETNA to calculate graph theory network metrics including Assortativity, Hierarchy, Small Worldness, Global and Local Efficiency. Correlations between brain metrics and clinical variables (e.g. APGAR scores, severity of HIE score, first postnatal gas PH, cord blood PH, etc.) were assessed to identify neural markers associated with severity of HIE.

Results: 16 neonates with HIE [12 males, mean (SD) gestational age 38.9 (1.9) weeks & birth weight 3175 (585) g; mild HIE (n = 3); moderate HIE (n = 11), mean age at scan = 8 days]. We found a trend towards reduced Global efficiency and Assortativity in neonates with moderate HIE compared to mild HIE. Moreover, first postnatal gas pH was associated with higher Assortativity (r=-.64, p<.01) and lower Hierarchy (r=.56, p<.05). These results suggest that perinatal injury can result in compensatory changes in brain connectivity including hyperconnectivity and increased local processing. This can lead to rigidity in functional connectivity and limited neuroplasticity which could increase the risk of neurodevelopmental outcomes.

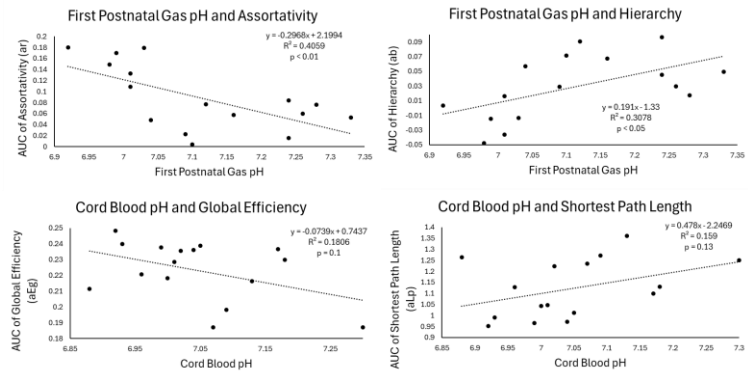

Figure 2. Correlations between brain network metrics and clinical variables indicating severity of HIE. Top panels show the association of first postnatal gas and Assortativity (left) and Hierarchy (right) brain metrics. Bottom panels show the correlation between cord blood pH and Global Efficiency (left) and Shortest Path Length (right) brain metrics.

Neural Correlates of Cognitive Fatigue in Regular Cannabis Users and Non-users: A Pilot fNIRS Study

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Abstract: Cognitive fatigue impairs performance across multiple domains, yet how regular cannabis use affects fatigue remains unclear. This pilot study investigated neural and behavioural correlates of cognitive fatigue in abstinent cannabis users versus non-users. Twenty-six participants (18 non-users, 8 cannabis users) completed cognitive tasks before and after a 60-minute sustained attention task. Functional near-infrared spectroscopy monitored prefrontal cortex activation. Both groups reported increased subjective fatigue, yet showed opposing neural patterns: non-users exhibited increased prefrontal oxygenated hemoglobin (110% increase), while cannabis users showed decreased values (positive to negative). These divergent hemodynamic responses suggest different neural adaptation patterns, warranting investigation with larger samples.

Introduction: Cognitive fatigue occurs after prolonged performance of cognitively demanding tasks, leading to a deterioration in cognitive processes[1]. The brain regulates fatigue through a dual regulation system: facilitation (to maintain performance) and inhibition (to reduce effort)[2]. Cannabis use and cognitive fatigue both impact the prefrontal cortex, particularly the dorsolateral prefrontal cortex, which may indicate potential interaction[1,3]. However, it is unclear whether regular cannabis users have different neural responses to cognitive fatigue.

Research Question: Do cannabis users exhibit different neural and behavioural patterns of cognitive fatigue development compared to non-users when performing sustained attention tasks?

Hypothesis: During cognitive fatigue, cannabis users will exhibit lower maximum activation in prefrontal regions.

Methods: Twenty-six participants (18 non-users, 8 regular cannabis users after 24-hour abstinence) completed cognitive tasks before and after a 60-minute Sustained Attention to Response Task (SART) designed to induce fatigue. Cognitive domains were assessed using the N-Back, Wisconsin Card Sorting Test (WCST), Digit Symbol Substitution Test (DSST), Continuous Performance Task (CPT), Stroop, and Stop Signal tasks. Functional near-infrared spectroscopy (fNIRS) continuously monitored prefrontal cortex activation across 20 channels organized into 7 regions of interest.

Results: Both groups reported increased subjective fatigue (Visual Analogue Scale for Fatigue) post-SART. Behaviourally, most cognitive tasks showed practice effects rather than fatigue-related decrements. fNIRS revealed divergent patterns: non-users showed 110% increase in prefrontal HbO values post-SART, while cannabis users showed shifting from positive to negative HbO values. Effect sizes for group differences were medium to large: Stroop, d = -0.58; DSST, d = -0.55; and CPT, d = -0.50, despite not reaching significance due to limited power.

Conclusions: This exploratory study suggests abstinent cannabis users and non-users show opposing neural adaptation patterns to cognitive fatigue. While underpowered for definitive conclusions, the divergent hemodynamic responses warrant investigation with larger samples.

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Exploring the Link Between Social Media Use, Mental Health, and Social Brain Connectivity in Adolescents

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Abstract: Adolescent social media use is rising, but associated mental health outcomes and neural correlates in the social brain remain unclear. This study investigated whether social media use impacts the psychological well-being and resting-state social brain connectivity of adolescents. Participants reported internalizing and externalizing symptoms alongside social media use behaviours, while fNIRS was used to assess functional connectivity between the mPFC and bilateral TPJ. No significant associations between social media use and mental health were observed, however, gender significantly moderated the relationship. A pattern of positive coupling was demonstrated between the mPFC and bilateral TPJ in association with social media use.

Introduction: Social media use has become increasingly prevalent among youth in recent years. Adolescents likely face a heightened susceptibility to the impacts of social media use, as this developmental period is marked by numerous physiological and psychological changes that increase adolescents' sensitivity to social information. Despite the potential consequences, there is still no clear consensus regarding the impact of social media use on adolescent mental health. Social media use may also affect the connectivity of brain areas involved in important social processes, like the medial prefrontal cortex (mPFC) and bilateral temporoparietal junction (TPJ), which undergo considerable development in adolescence. Structural differences in these regions have been observed in line with increased social media use, however, functional differences within the social brain network have yet to be delineated. Therefore, the present study sought to examine how social media use is associated with the mental health of adolescents and the resting-state functional connectivity among social brain regions.

Method: 48 healthy participants (M_{age} = 14.15, *SD* = 1.96 years) reported internalizing and externalizing symptoms using the Strengths and Difficulties Questionnaire (SDQ) and screen time/social media use behaviours using the SCREENS Questionnaire (SCREENS-Q). Functional near-infrared spectroscopy (fNIRS) was used to record resting-state functional connectivity between the mPFC and TPJ. Behavioural data were analyzed using multiple linear regression models, adjusted for age and gender. fNIRS data were pre-processed and analyzed using Brain AnalyzIR and Homer2 toolboxes alongside custom scripts. Pairwise Pearson correlations were computed across all channels and individual matrices were correlated with social media use to produce a group-level connectivity map.

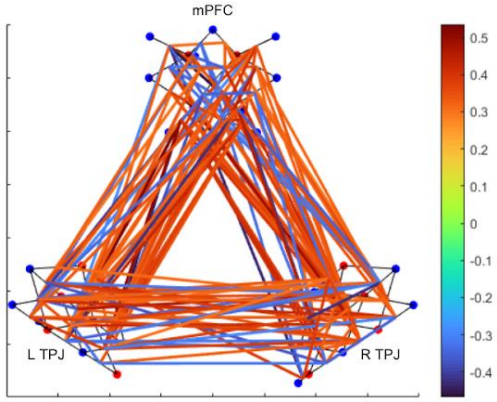

Figure 1: Group-level connectivity map.

Results: Social media use was not found to be a significant predictor of internalizing (*B* = -0.004, *p* = .535) nor externalizing (*B* = 0.009, *p* = .215) symptoms after adjusting for age and gender. However, exploratory analyses revealed that gender was a significant moderator. A significant social media x gender interaction effect (*B* = –1.46, *p* = .018) was observed for conduct difficulties. Simple slopes analyses revealed that higher social media use was significantly associated with greater conduct difficulties in females only (*B* = 1.42, *p* = .034). Visual inspection of the group-level connectivity map suggested a pattern of more positive coupling (in red, refer to Figure 1) across the mPFC and TPJ with greater social media use. However, analyses have not been FDR-corrected and should therefore be interpreted with caution.

Conclusions: Social media use was associated with variation in social brain connectivity, but its link to adolescent mental health remains unclear. Specific features of social media use, such as content type and engagement style, should be explored in future studies to identify more precise relationships.