Brain Quantum Imaging

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PTB

Book of Abstracts

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1 - Poster

A Multi-person Naturalistic Hyperscanning OPM-MEG System

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1. Objective

Understanding the neural mechanisms of real-world social interaction is a key challenge in neuroscience. Traditional neuroimaging modalities—fMRI, EEG, and SQUID-MEG—face inherent trade-offs in spatial resolution, temporal precision, sampling rate, and tolerance to movement, limiting their ability to capture the fast, distributed brain dynamics underpinning naturalistic multi-person exchanges. The advent of optically pumped magnetometers (OPMs) enables wearable MEG systems that combine high spatiotemporal resolution with participant mobility, opening new possibilities for hyperscanning in ecologically valid settings.

2. Methods

We present the first four-person OPM-based hyperscanning MEG system optimized for naturalistic interaction studies. Each participant wore a 64-channel OPM array (intrinsic sensor noise < 10 fT/$\sqrt{\text{Hz}}$) integrated with a custom matrix-coil magnetic field control system. This system performs high-order gradient compensation and real-time, low-noise interference suppression, enabling stable measurements within a 2m $\times$ 2m $\times$ 1.2m shielded space while participants move freely and engage naturally.
Two ecologically rich paradigms were implemented: (1) a multi-person game-theoretic decision-making task, and (2) a cooperative map-based information transfer task. Behavioral events were tracked via synchronized video and motion capture. MEG data were preprocessed (filtering, ICA artifact removal, source reconstruction), and inter-brain metrics—phase-locking value (PLV) and Granger causality—were computed to quantify synchrony and directional information flow.

3. Results & Conclusion

In the decision-making task, oscillatory features in centro-parietal and temporal regions allowed classification of individual strategies with accuracies up to 96.7%, demonstrating robust neural decoding of social decision processes. In the information transfer task, cooperative conditions elicited distinct frontal and occipital activations and significantly enhanced right temporo-parietal inter-brain connectivity ($P < 0.05$). Synchrony strength correlated with task performance ($^2 = 5.5$, $P < 0.05$), revealing a functional link between neural coordination and collaborative success.

4. Discussion

This system offers three major innovations:
(1) **Scalable multi-person compatibility** – enabling synchronous, high-quality MEG recording from four participants without compromising comfort or ecological validity.
(2) **Advanced magnetic field control** – achieving millimeter-scale stability in a large shielded volume via dynamic interference suppression.
(3) **Real-world cognitive capture** – successfully decoding strategies and predicting behavioral performance in complex, interactive tasks.
By bridging the gap between high-resolution neuroimaging and naturalistic social neuroscience, this platform empowers new investigations into how brains coordinate during real-world interactions. Beyond basic research, its mobility, scalability, and decoding capability position it for future applications in education, clinical assessment, and adaptive human–machine interaction.

2 - Poster

Distort to inform: can OPMs distinguish between true and distorted anatomical models?

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MEG signals derive predominantly from pyramidal neurons, which are oriented perpendicularly to the cortical surface. Previous work using head-casts to minimise co-registration errors in conventional MEG has shown that MEG functional estimates depend on precise anatomical models (Little et al., 2018). Specifically, the idea behind this approach is to quantify the reconstruction performance of different algorithms by applying them over progressively more deformed anatomical models (i.e., cortical meshes) and evaluate the resulting model evidence (i.e., free energy). In this context, one should expect model evidence to be maximised when the estimated current distribution lies on the true cortical mesh.

The goal here is to identify the key constraints that we might come across when using this approach to validate future OPM current flow estimates. To do so, we make use of simulations of OPM data contaminated by different levels of unmodelled noise. For example: error in the estimate of the true sensor positions or orientations and the effects of gain changes that are spatially correlated with environmental interference. We leveraged diffeomorphic brain shape modelling (Ashburner et al., 2019) to provide more realistic surrogate brains deformed along a parameter space consistent with the healthy population. Mean surface distortions ranged from 0.5 to 4 mm. We used two source reconstruction algorithms (Empirical Bayes Beamformer - EBB and Minimum Norm - IID).

We find that, for sparse simulated left-motor activity, only the evidence for the EBB algorithm (with corresponding sparse assumptions, in the absence of other errors) peaked at the true anatomy. We go on to quantify the amount of error (in mm) to the true cortical mesh that one might expect in empirical recordings (given gain, position and orientation errors). This work allows us to objectively quantify the validity of any MEG analysis pathway, from hardware gain distortions, to co-registration error, to inversion assumptions.

Importantly, the combination of large scale simulations, Bayesian inference and realistic anatomical distortions constitutes a principled framework to formulate and test specific hypotheses to validate non-invasive brain imaging in both health and disease.

3 - Poster

Investigating hippocampo-cortical phase-amplitude coupling in aging and Alzheimer's disease using bispectral analyses of MEG recordings

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Alzheimer's disease (AD) is characterized by progressive neurodegeneration and cognitive decline. It has been suggested that cognitive decline associated with AD may not solely be due to the loss of neurons but also to impairments in the temporal coordination of distributed neuronal activity. Memory studies in healthy subjects have reported modulations of non-linear across-site phase-amplitude coupling (PAC) between cortical gamma and hippocampal theta oscillations. Since memory deficits present a cardinal symptom in patients with AD, we hypothesized that AD affects resting-state PAC between hippocampal and cortical oscillations compared to healthy controls. Using non-invasive MEG recordings from 78 AD patients and 70 age-matched controls, we examined whether hippocampo-cortical PAC is disrupted in AD and characterized its spatial distribution.

Using antisymmetrized bispectral analysis – a robust way to estimate across-site PAC – and the recommended approach for hippocampal source reconstruction, PAC was estimated between the source-reconstructed signals of the hippocampus and cortical regions. Results indicate significant disruptions in hippocampo-cortical PAC in AD, with consistent impairments for both hippocampi in the frontal, parahippocampal, and posterior cingulate cortices. Furthermore, In a correlation analysis, significant associations were found between hippocampo-cortical PAC values and MMSE scores in AD patients group. The direction of these correlations corresponded to the group-level PAC contrasts. For instance, in regions where the AD group exhibited reduced hippocampo-cortical PAC compared to the control group, a positive correlation with MMSE scores was observed – indicating that greater cognitive impairment (i.e., lower MMSE scores) was associated with lower hippocampo-cortical PAC values. Complementary spectral power analyses replicated previous findings in AD, revealing a global increase in delta–theta activity, a temporal decrease in alpha power, and a global reduction in beta band activity. Overall, this work provides novel insights into electrophysiological alterations in AD and highlights PAC as a potential marker of disease-related network dysfunction.

4 - Oral Presentation

Toward Biomagnetic Sensing with a High-Sensitivity Diamond Quantum Magnetometer

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Diamond quantum magnetometers (DQMs) based on negatively charged nitrogen–vacancy (NV) centers in diamond are promising tools for biomedical applications. Their high sensitivity under ambient conditions at room temperature enables a reduced standoff distance from the measurement object such as the brain in magnetoencephalography (MEG).

We developed a sensitive DQM with a sensitivity of 6 pT $Hz^{-1/2}$, aiming at MEG applications in living rats and humans. The sensor is compatible with MEG measurements and allows a minimum standoff distance of about 1 mm. We evaluated its performance in practical MEG measurements using a phantom. In addition, we attempted measurements of an evoked field in rats. We will discuss recent progress in improving the sensitivity of our DQM and in applying it to biomagnetic sensing.

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5 - Oral Presentation

Longitudinal Changes of Aperiodic and Periodic Cortical Activity at Rest in Parkinson's Disease

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The progressive motor dysfunction of Parkinson's disease (PD) has been linked to widespread functional changes within the basal ganglia-thalamic-cortical network, particularly in the beta frequency range (13-30 Hz). However, the longitudinal evolution of cortical neurophysiological changes and their relationship to clinical progression remain poorly understood, particularly when accounting for the aperiodic component of the neuronal signal.
We aimed to close this gap by conducting a longitudinal resting-state magnetoencephalography (MEG) study in 27 persons with PD and 30 healthy individuals with a mean follow-up time of four years. Clinical symptom progression was assessed using the annual change in MDS-UPDRS-III motor scale, adjusted for changes in dopamine replacement therapy. Neurophysiological changes were assessed using source reconstructed MEG data parcellated into 68 cortical regions, from which power spectra were parameterized to separate oscillatory peaks in the beta, alpha (8-12 Hz), and theta (4-8 Hz) frequency bands from the aperiodic component described by its exponent and offset.
Neurophysiologically, we observed that a steepening of the aperiodic slope in the left sensorimotor region was associated with a progression of rigidity, and that an increase in the aperiodic offset with an increase in bradykinesia. No significant PD-related changes in oscillatory peak power in the theta, alpha or beta frequency ranges were detected.
Using partial least squares regression to predict future motor disease progression from baseline neurophysiological features, the predictive model was able to explain 19.5 % of the variability in motor progression in an independent validation cohort consisting of 18 persons with PD, with the aperiodic features contributing most to the predictions.
Our findings demonstrate a close relationship between cortical PD-related neurophysiological alterations and longitudinal changes in symptom severity. The results emphasize the importance of separating aperiodic neural activity from periodic oscillations since we show that a progressive steepening of the aperiodic exponent in the sensorimotor region represented the most prominent PD-related longitudinal cortical change, potentially reflecting a progressive shift of the excitatory-inhibitory balance towards inhibition. Furthermore, our results highlight the potential predictive value of simple resting-state neurophysiological features for predicting future disease progression in PD.

6 - Poster

How musicality enhances top-down and bottom-up selective attention: Insights from precise separation of simultaneous neural responses

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Everyday listening environments, from crowded conversations to orchestras, require the brain to extract target sounds from complex mixtures. A central challenge is that neural activity evoked by different sounds overlaps in time, making it difficult to assign responses to their source. Frequency-tagging addresses this by embedding each stimulus with a unique modulation frequency, enabling its individual neural response, also known as the auditory steady-state response (ASSR), to be identified and analyzed separately with high precision even when presented simultaneously. However, weak signal-to-noise ratios have limited its use in elucidating cognitive processes. Here, we combined frequency-tagging with a machine learning decoder, specialized for ASSRs, to extract attentional effects and their correlations with behavior.

Across two magnetoencephalography (MEG) experiments, participants attended to one of two overlapping melodies, each amplitude-modulated at 39 Hz or 43 Hz with 100% modulation depth to elicit distinct ASSRs. Experiment I (N = 28) used alternating tone onsets to dissociate top-down (cue-driven) from bottom-up (stimulus-driven) attention that is reliant on both pitch and timing, whereas Experiment II (N = 20) presented fully concurrent tone onsets to maximize the engagement of top-down attention to pitch only. The decoder reliably discriminated attention conditions only at the tagged frequencies, reaching AUC values between 0.54–0.63.

Behaviorally, task performance correlated strongly with individual musicality, with correlation coefficients scaling with complexity (r = 0.64–0.79). Neural analyses revealed a double dissociation in frontoparietal attentional mechanisms: top-down attention correlated positively with musicality and performance in the left inferior parietal lobe and prefrontal cortex, whereas bottom-up attention correlated negatively with performance in the right inferior parietal lobe and orbital gyrus. This opposing pattern indicates that left-lateralized networks preferentially support top-down mechanisms, whereas right-lateralized networks index vulnerability to salient bottom-up distractions.

Temporal dynamics further highlighted individual strategies. Sliding-window analyses in Experiment II revealed a bimodal distribution of peak selective-attention times, separated at 0.5 s from tone onset. Participants whose peaks occurred later than 0.5 s performed significantly better and tended to be more musical. Source analyses localized these sustained late-phase effects to the right prefrontal cortex, suggesting that musical training sharpens mechanisms for maintaining attention over time.

Together, these findings demonstrate that musicality enhances selective auditory attention by strengthening top-down control, suppressing bottom-up distraction, and sustaining attention in frontoparietal circuits. Beyond music, this work establishes the combination of frequency-tagging with machine learning as a sensitive approach for detecting and disentangling subtle cognitive effects in complex auditory environments.

7 - Poster

OPM-FLUX – an open-source analysis pipeline for OPM-MEG

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MEG systems based on Optically Pumped Magnetometers (OPMs) are the next generation of MEG systems for non-invasive brain imaging. Unlike conventional MEG, which relies on cryogenic cooling and rigid helmets, OPMs operate at room temperature, are wearable, and can be placed directly on the scalp. This enables the detection of stronger signals, and the technique has great promise for, e.g., paediatric recordings. To support researchers in analysing the complex data produced by OPM systems, we introduce OPM-FLUX (http://www.neuosc.com/flux), an open-source, standardised analysis pipeline developed specifically for OPM MEG data based on the MNE-Python toolbox. OPM-FLUX is designed to guide researchers through all the steps of OPM signal analysis, including preprocessing, artefact removal, noise attenuation, event-related fields, time-frequency spectral analysis, source localisation, and multivariate pattern analysis. Each analysis step is implemented and documented in Jupyter Notebook scripts used to analyse an OPM dataset on spatial attention, which is also provided. Each chapter combines code with detailed explanations, justifications for parameter choices, and graphical outputs. In each chapter, we also provide text suggestions to be used for preregistration and publications . This aim is to support learning, making advanced analysis methods accessible to users who are new to the field, but also to provide a standard for best practices. OPM-FLUX is also designed to develop over time as OPM technology and analysis methods improve. It is a community project, and researchers are encouraged to contribute and help it develop further. OPM-FLUX and the training datasets are free and open for everyone to use. It follows the principles of open science, making tools and knowledge available to researchers worldwide, including those with limited resources . The pipeline is regularly updated and will develop as OPM technologies are improved. By providing a clear and tested procedure to analyse OPM data, it helps more scientists use OPM-MEG and support rigour in data analysis. OPM-FLUX can be used for self-studies, but also in educational settings to teach students and new users how to analyse OPM data.

8 - Poster

Revealing Beta Burst Waveform Diversity with a Topological Approach

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Neural oscillations play a crucial role in human brain functioning. Among these rhythms, beta oscillations (~13–30 Hz) have been extensively studied, yet their functional roles remain debated. This debate centers on whether beta activity primarily reflects the maintenance of brain states or actively supports the dynamic reconfiguration of neural processes. Methodologically, traditional approaches often treat beta activity as a sustained amplitude-modulated rhythm, yet recent studies show it is better described as transient bursts. These bursts vary in occurrence rate, duration, peak frequency, and amplitude, and such features have been shown to differ across behavioral contexts and clinical conditions, underscoring their functional relevance. Yet one critical aspect remains largely unexplored: the waveform shape. Oscillatory waveform shapes have been linked to underlying physiological mechanisms in several studies, suggesting that different waveform motifs may reflect distinct neural processes. In this study, we therefore aim to test whether specific waveform shapes are associated with different functional states.

Here, we present a comprehensive analysis pipeline to systematically study beta burst waveforms. The pipeline was validated on simulated data, where it successfully recovered ground-truth waveform structure, and can now be applied to real data.

On simulated data, an iterative burst detection algorithm identified bursts and provided their waveforms and features. For the waveform analysis, we adapted a topological data analysis (TDA) approach to assess beta burst waveforms. After that, each waveform was mapped into a high-dimensional space defined by its time samples and duration. This representation allowed us to analyze the geometry of beta bursts. We then applied TDA to capture the topology of this waveform space. To guide dimensionality reduction, intrinsic dimensionality was first estimated. Subsequently, the data were embedded into a low-dimensional space using Uniform Manifold Approximation and Projection (UMAP), which preserves local structure. Within this space, Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN) identified clusters of similar burst waveforms.

In the simulated data, topological measures indicated that beta bursts are best described as a continuum of events, with local clustering reflecting waveform motifs within that continuum. This validation demonstrates that our pipeline can robustly recover ground-truth waveform structures and lays the foundation for its application to real MEG data. Beyond methodological novelty, the pipeline enables us to directly address whether beta burst waveforms

represent a continuum of shapes or can be meaningfully divided into discrete classes, and how these relate to their functional roles.

9 - Poster

Tailored Alkali Vapor Cells for Innovative Applications in Magnetometry

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The capabilities of Leibniz IPHT in the field of alkali vapor cell fabrication are presented. At Leibniz IPHT, wafer-based processes (anodically bonded glass–silicon–glass stacks) are employed to realize vapor cells with high reproducibility, well-defined geometries, and a broad range of functionalization options. This approach provides decisive advantages over conventional glass-blown cells, in particular the possibility to tailor cell architecture and optical properties with high precision.
Functional elements are directly integrated into the cell structure, including transparent indium tin oxide (ITO) heaters, adapted anti-reflection coatings and integrated mirrors. In addition, passivation techniques and laser-based cleaning of optical windows ca be applied to increase lifetime and maintain optical quality. These functionalizations and methods can be flexibly combined, depending on the application require¬ments. The cells are currently filled using cesium (via cesium azide or dispenser pills) and will soon also be available with rubidium-based fillings.
These technological capabilities enable the realization of application-specific designs with a high degree of innovation, such as vapor cells with integrated microfluidics for measurements on magnetotactic bacteria, or multi-pixel camera-type vapor cells for magnetic field imaging.

10 - Oral Presentation

Towards spatially resolved, non-invasive single trial detection of high-frequency synchronous population spikes using SQUIDs

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Magnetoencephalography (MEG) based on ultra-sensitive magnetometers typically measures biomagnetic fields caused by postsynaptic potentials covering a frequency range from near-DC to up to some hundred Hertz. Superconducting Quantum Interference Device (SQUID) based instruments have been the technology of choice for this task for decades owing to their extraordinary sensitivity of around 2 $\mathrm{fT}/\sqrt{\mathrm{Hz}}$ for commercial and custom-built multi-channel systems. In recent years, non-cryogenic Optically Pumped Magnetometers (OPMs) have emerged as an alternative thanks to their flexibility, even though the noise performance and bandwidth remain inferior.

A wealth of information can be gained from those studies; however, neuronal activity due to action potentials is hardly investigated non-invasively via MEG. Studies, utilizing electrostimulation of the median nerve, have shown that synchronized neuronal spiking manifests itself as high frequency somatosensory evoked responses (hfSERs) with a typical frequency of around 600 Hz. As the amplitudes are in the range of 10s of femtotesla, their recording required hundreds of averages with conventional SQUID-MEG systems, precluding any investigation of their variability.

In this presentation, I will show that ultra-sensitive, single-channel SQUID hardware can detect hfSERs at a single trial level which permits analysis of correlations between the high frequency neuronal spiking and the low frequency post-synaptic response N20. This opens the path towards non-invasive investigation of neuronal input output processing. We also demonstrate that careful design enables the single trial detection of hfSERs in simultaneous ultra-low noise electroencephalography (EEG) and ultra-sensitive MEG allowing the combination of these complementary methods. In addition, the design of our new ultra-low noise, 12-channel SQUID-based MEG system will be presented. With a projected field noise of approximately 370 $\mathrm{aT}/\sqrt{\mathrm{Hz}}$, it will be capable of measuring hfSERs at the single trial level.

The final multi-channel SQUID-MEG & EEG setup will enable the examination of how population spiking activities in neighbouring cortical regions interact, showing that SQUIDs remain relevant in today's MEG research. Ultimately, combined ultra-sensitive MEG and EEG would allow for real-time, spatially resolved measurements of low and high frequency activity, further reducing the gap between invasive and non-invasive measurements.

11

Unveiling the Neural Correlates of Awe: A VR-EEG Source-Level Connectivity Framework

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Recent advances in non-invasive neuroimaging and electrophysiological methods have significantly deepened our understanding of the brain function. Yet, the neural mechanisms underpinning complex emotions such as awe remain largely elusive. Awe, conceptualized as an emotional response to vast and overwhelming stimuli like grand natural phenomena, has been linked to positive psychological outcomes including enhanced emotion regulation and well-being. Despite this promising evidence, awe experiences are still underexplored in affective neuroscience. Building on these premises, the SUBRAIN study proposes a multimodal experimental framework to elicit awe and investigate its neural bases. Awe was induced through carefully crafted Virtual Reality (VR) scenarios designed to provide immersive and ecologically valid laboratory experiences and electroencephalographic (EEG) data was simultaneously recorded. To characterize the underlying brain mechanisms, functional connectivity patterns associated with awe-inducing VR scenarios were compared with those elicited by a neutral VR one.

EEG data was collected from 20 healthy volunteers (10 F, 10 M) during the exposure to different VR scenarios. Data was filtered (1–120 Hz, notch at 50 Hz), down-sampled to 250 Hz, and cleaned from artifacts via the independent component analysis. The resulting signals were re-referenced to the average reference and imported in Matlab for source-level analysis. To overcome EEG's inherent spatial limitations due to volume conduction, source-level analysis was conducted using the linearly constrained minimum variance beamformer. Principal component analysis was then applied within each region of interest to aggregate regional activity, and functional connectivity was estimated using robust metrics designed to minimize spurious interactions. Specifically, to assess undirected and directed influences among brain regions, we implemented: (i) imaginary part of coherence, (ii) maximized imaginary coherency, and (iii) time-reversed Granger causality. Statistical analyses were employed to examine both commonalities and differences in brain connectivity between the awe-inducing VR scenarios and the neutral VR one.

This integrative approach not only advances the methodological integration of VR, source-reconstructed EEG, and functional connectivity analysis as a powerful framework for studying emotions but also yields novel insights into the neurophysiological mechanisms underlying VR-based awe experiences. Particularly, within this contribution, by contrasting the awe-inducing VR scenarios with the neutral VR one, we report distinct connectivity patterns associated with awe, shedding light on the neurophysiological bases of this complex and transformative emotion. Clarifying these mechanisms holds great potential, paving the way for new directions in affective neuroscience research.

12 - Poster

Evaluating and improving the extraction of MEG and/or EEG activity from brain areas of interest using cross-talk function

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Neuroimaging studies often analyze and interpret results by referring to specific areas of the brain defined according to various parcellations based on anatomical, cytoarchitectural, functional, and/or connectivity-based criteria. In MEG and EEG (M/EEG) analyses, it can be convenient to extract time series of activity that originates from such regions of interest (ROIs). The results of the subsequent analyses (e.g., connectivity) are then attributed to the selected ROIs.

Due to the spread of electric and magnetic fields, M/EEG recordings contain a mixture of activity of all sources within the brain. Commonly used approaches for extraction of ROI activity only partially alleviate this problem, and field spread remains a challenge even on the level of ROI time series. Because of the remaining field spread (RFS), extracted time series capture activity not only from the target ROI but also from other (and not necessarily neighboring) ROIs. The amount of RFS can strongly affect the validity of interpretations: with more RFS, the extracted time series becomes less representative of the target ROI. Unfortunately, both the amount and the pattern of RFS are generally not known in practice.

In this study, we apply the concept of cross-talk function (CTF) to analyze contributions of all sources within the brain to the extracted signal, thereby quantifying the degree of RFS. We show how CTF is related to the extraction of ROI activity and estimation of inter-regional connectivity. We observe that effects of RFS on the extraction of ROI activity are non-uniform, with deeper ROIs being more prone to capturing activity from ROIs that are closer to recording sensors. Finally, we show that CTF can be used to optimize the extraction of ROI activity but caution is required to avoid overfitting, especially if only a template head model is available for the analysis. Overall, our results illustrate how CTF can be used as a diagnostic tool for quantifying and optimizing the RFS and extraction of ROI activity.

13 - Oral Presentation

Resting-state alpha power correlates with cortical microstructure

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Brain activity related to cognition is commonly assessed with electrophysiological recordings, such as magnetoencephalography and electroencephalography (EEG/MEG). While it is commonly believed that pyramidal neurons generate EEG/MEG signals, our detailed knowledge about the generation mechanisms at the cellular level remains very limited.
In this study, we combined EEG/MEG with histological data and high-resolution magnetic resonance imaging (MRI), aiming to bridge functional and anatomical perspectives on brain organization. To do so, we analyzed the data in two ways: between regions and between participants. For between-region analysis, we used datasets from different samples: EEG, MEG, high-resolution structural MRI, and histological sections stained for cell bodies (i.e., cytoarchitecture) from the post-mortem brain. We correlated averaged-over-participants distributions in a pairwise fashion between variables of all three modalities: resting-state EEG/MEG variables were alpha power, low beta power, and high beta power; MRI variables were myelin content at different cortical depths; and cytoarchitectonic variables were thickness of cortical layers and staining profile derivatives (profile mean and profile skewness). For between-participant analysis, we collected a joint dataset of resting-state MEG and high-resolution MRI (31 participants). Here, we correlated resting-state alpha power and myelin content estimates at different cortical depths in each vertex (or region).
We found that between regions, alpha power correlated positively with the thickness of layer IV and with myelin content at the level of layer IV, whereas between participants, alpha power correlated negatively with myelin content at the level of layer IV, most prominently over the frontal and central cortex. The opposite directions of relations indicate that different factors may play a role between regions and between participants. Since the myelin content estimate includes myelin from both excitatory pyramidal neurons and inhibitory interneurons, we argue that the positive correlation of alpha power and myelin content may be explained by the number and activity of excitatory neurons, and the negative correlation between participants may be explained by the variability in the number and activity of inhibitory neurons.
The current study contributes to ongoing research attempting to reveal the structural laminar correlates of electrophysiological signals, especially neural oscillations, in the human brain. A clear mapping between laminar cell distributions and brain dynamics will help to further understand the link between brain structure and its function.

14 - Poster

High-frequency visual stimulation can increase medial temporal lobe ripple oscillation density

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Background: Flickering visual stimulation can evoke neural oscillations, which can influence ongoing brain activity. Electrophysiological recordings of neural oscillations in the ripple band (80-180 Hz) showed that these high-frequency oscillations occur in the neocortex and the hippocampus, that they phase-synchronize across long distances, and that ripple oscillations in the neocortex often precede those in the hippocampus during wakefulness. It is therefore possible that the neocortical ripple oscillations propagate beyond sensory areas to the hippocampus, inducing ripple oscillations.
Methods: To test this hypothesis, we conducted an experiment (N = 8) in humans, using ultra-high frequency visual stimulation (UHV-stimulation) to evoke ripple oscillations recorded through electrodes implanted in or near the hippocampus. Although hippocampal ripple oscillations, so-called sharp-wave-ripples (SWRs), mostly occur during quiet rest or slow-wave-sleep, we aimed to increase their abundance using visual stimulation during wakefulness. We hypothesized that UHV-stimulation would increase the number of SWRs relative to an eyes-open resting-state baseline.
Results: In line with this hypothesis, we observed significantly more SWRs per second during periods of stimulation compared to a static-stimulus baseline before and after the stimulation.
Conclusion: This indicates that UHV-stimulation can be used as a safe noninvasive tool to influence SWRs, which offers the potential to improve memory. In the next step, these results from a limited sample of participants suffering from epilepsy need to be replicated in a larger sample of healthy participants with non-invasive recording methods such as OPM-MEG, which are suitable to record from deeper sources in the brain, for example the Hippocampus.

15 - Oral Presentation

An integrated virtual reality platform for naturalistic neuroimaging with magnetoencephalography

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Advancing our understanding of the neural mechanisms that support natural behaviour requires imaging methods that work under conditions of movement and realistic sensory input. Wearable magnetoencephalography (MEG) with optically pumped magnetometers (OPMs) offers millisecond temporal and millimetre spatial resolution in freely moving participants. Yet, combining OPMs with virtual reality (VR)—a tool for delivering immersive in fully controlled environments—has been limited by electromagnetic artefacts from conventional head-mounted displays (HMDs). Here, we introduce and validate a new OPM-compatible VR platform that enables naturalistic neuroimaging without compromising signal quality.

We designed a HMD built from low-noise LCD panels and open-source electronics, achieving magnetic interference levels below those of commercial systems. The device integrates seamlessly with optical motion capture and standard VR development environments (Unity, Unreal Engine), supporting interactive behavioural paradigms. We validated the system through a combination of hardware-level tests and seven experimental tasks across perceptual and cognitive domains.

Our findings demonstrate that the headset introduces negligible magnetic artefacts and preserves source localisation precision. In experimental tests, the system robustly reproduced canonical neural signatures: alpha-band increases with eye closure, lateralised visual responses to flickering checkerboards, beta-band suppression and motor-cortex activation during grasping, and theta-band engagement of medial frontal gyrus and hippocampus during N-back and imagination tasks.

These results establish that our platform enables reliable, whole-brain OPM-MEG recording in immersive VR environments. Its open-source design provides a flexible, scalable foundation for investigating embodied cognition and naturalistic behaviour in human neuroscience.

16 - Poster

Voluntary movement modulates high frequency activity in the human spinal cord

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The spinal cord serves as both the entry point for somatosensory information and the final pathway for motor output in the central nervous system. Emerging evidence indicates that cognitive and behavioral states actively regulate spinal sensory processing. However, direct physiological evidence of interacting sensory and motor pathways in the human spinal cord is rare, given limitations in noninvasive recording techniques.

Combining noninvasive EEG recordings via electrodes placed around the neck with invasive epidural recordings from the human spinal cord, we recently revealed a top-down modulation of spinal sensory processing by temporal expectation, specifically in high-frequency signals (~600 Hz) occurring 13–16 ms after median nerve stimulation (Stenner, Marquez Nossa, et al., Science Advances 2025). Here, we report preliminary findings from a study of pre-movement sensory gating at the level of the human spinal cord. In non-human primates, descending motor commands elicit spinal presynaptic inhibition of sensory inputs beginning approximately 400 ms before detectable EMG activity, indicating pre-movement sensory gating (Seki, Perlmutter & Fetz, Nat. Neurosci., 2003). We asked whether a similar pre-movement gating phenomenon is evident in high-frequency signals from the human spinal cord.

In each trial, participants were instructed either to flex the wrist of their left or right hand (Go trials) or to remain still (NoGo trials). Median nerve stimulation was delivered to either the moving hand or the resting hand in Go trials, and to either resting hand in NoGo trials. Stimulation occurred approximately 150 ms before the expected EMG onset, allowing comparison of signals from stimulation ipsilateral or contralateral to movement or rest. While no gating of the spinal ERP was observed, we identified a movement-related enhancement of high-frequency activity (400–800 Hz) occurring 10–16 ms after stimulation, both when stimulating the moving or resting hand in Go trials, relative to NoGo trials.

Our findings indicate that voluntary movement modulates spinal somatosensory activity prior to detectable muscle activation, specifically affecting high-frequency components of the induced response. These high-frequency signals may reflect a continuous top-down control mechanism, which could be investigated further—and with greater accessibility—using novel approaches such as OPM-magnetospinoencephalography (Mardell et al., J. Neurosci. Methods, 2024).

17 - Poster

Neurophysiological signatures of depression and treatment resistance: A resting-state MEG study

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Background.
Major depressive disorder (MDD) severely impairs quality of life through persistent mood and cognitive symptoms. Around 30% of MDD patients suffer from treatment-resistant depression (TRD), defined as insufficient response to two pharmacological interventions. Emerging research indicates that TRD may be characterized by distinct neurophysiological patterns. Magnetoencephalography (MEG), with its high temporal and spatial resolution, disentangles phenotypic differences between MDD and TRD. Here, we combined spectral power and functional connectivity analyses of resting-state MEG to identify neural signatures distinguishing the two conditions.

Methods.
We acquired eyes-closed resting-state MEG in three age- and gender-matched groups: neurotypical controls (NC, N=13), MDD (N=12), and TRD (N=22). Data preprocessing included filtering and ICA denoising. Power spectra and debiased weighted phase lag index (wPLI) connectivity were computed across six canonical frequency bands (delta, theta, alpha, beta-low, beta-high, gamma). Group differences were assessed using ANCOVA models controlling for age, gender, and pharmacological treatment. We further classified significant effects according to their group-specificity (MDD-specific, TRD-specific, or shared).

Results.
Spectral power analyses revealed region- and band-specific modulations. In MDD, parietal regions showed increased alpha and beta-low power; occipital regions showed increased alpha and beta-low but reduced delta and gamma power, distinguishing MDD from both TRD and NC. TRD power levels showed an intermediate trend between NC and MDD.
Connectivity analyses refined the patterns observed in the power analysis. While MDD showed power increases in alpha and beta-low bands, connectivity differences extended to theta and gamma, indicating that network-level abnormalities were not reducible to local amplitude shifts. TRD, despite exhibiting largely intermediate power levels, displayed distinct connectivity abnormalities in delta and beta-high bands, suggesting that its electrophysiological phenotype was less amplitude-driven and more consistently reflected in interregional coupling. Shared abnormalities across both patient groups emerged in theta, alpha, beta-low, and gamma connectivity, reinforcing their association with depression.

Conclusions.
By integrating spectral power and connectivity measures, our findings support the idea that TRD presents a neurophysiological profile distinct from treatment-responsive MDD. The joint analysis of local oscillatory power and interregional coupling underscores the value of MEG for parsing depression heterogeneity and identifying electrophysiological signatures of treatment resistance. These results support the development of MEG-based biomarkers to guide stratification and treatment planning in clinical populations.

18 - Poster

DBS-Evoked Cortical Responses due to GPi-DBS in Dystonia: Exploratory Evidence for Contact and Pulse Width Sensitivity

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Background. GPi-DBS is highly effective for dystonia, but programming parameters are still chosen empirically. DBS-evoked cortical fields (cEFs) may serve as objective markers. Source-level analysis can reveal the cortical generators of these responses and link them to therapeutic networks.
Objective. To investigate whether source-level cEFs differ by stimulation contact, pulse width, and clinical responder status.
Methods. Seventeen patients with idiopathic dystonia (mean age 57.5 ± 11.0 years; 10 cervical, 7 generalized; mean disease duration 15.7 ± 13.6 years) were included. Clinical severity was assessed with BFMDRS (Burke-Fahn-Marsden Dystonia Rating Scale) and TWSTRS (Toronto Western Spasmodic Torticollis Rating Scale) in ON vs OFF states. Responders were defined as 30% BFMDRS improvement (n=10). MEG recordings were acquired during monopolar 2 Hz GPi stimulation. Each patient completed ~240 trials per condition across four contacts and two pulse widths (90/120 s). Source modeling focused on precentral, frontal, and postcentral ROIs.
Results. GPi-DBS provided significant clinical benefit (median BFMDRS improvement 32%, TWSTRS 30%, both $p < 0.001$). Source-level analysis showed robust cEFs in mid- (19–88 ms) and late-latency (95–250 ms) intervals (FDR-corrected $p < 0.01$). Visual inspection suggested larger amplitudes for best-imaging compared to best-clinical contacts, and for pulse width 120 versus 90 s. Responders tended to display stronger activity in precentral and postcentral cortices than nonresponders.
Conclusion. Source-level analysis localized DBS-evoked responses to sensorimotor cortices, consistent with engagement of basal ganglia–thalamo–cortical pathways. These findings indicate that cEFs are sensitive not only to contact and pulse width, but also to clinical response, and that their cortical topography aligns with motor regions implicated in dystonia. This supports the potential of source-level cEFs as physiological grounded markers for optimizing GPi-DBS programming.

19 - Poster

A Canonical Microcircuit for Estimating E/I balance: Biophysical Modeling Identifies Different Cell Dysfunctions across Transdiagnostic B-SNIP Biotypes

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Background
Excitation/inhibition (E/I) balance is critical for maintaining healthy brain function and can be disrupted in various neurological and psychiatric disorders. Despite its importance, there are few tools to study E/I balance non-invasively in vivo in humans. We propose a canonical microcircuit model to estimate E/I balance from non-invasive magnetoencephalography (MEG), electroencephalography (EEG) and optically pumped magnetometer (OPM) recordings by parameterising global pyramidal cell and inhibitory interneuron excitability. We used this new model to examine changes in excitatory (E) and inhibitory (I) cell function across transdiagnostic psychosis Biotypes that were derived from clustering EEG and cognitive task measures in the Bipolar-Schizophrenia Network for Intermediate Phenotypes (B-SNIP) study (Parker et al., 2025).

Methods
EEG was recorded during an auditory paired-click and an oddball paradigm from healthy controls (n=269), and three transdiagnostic biotypes (B1: n=158, B2: n=154, B3: n=160) including people diagnosed with schizophrenia, bipolar, and schizoaffective disorder. We estimated pyramidal cell and inhibitory interneuron excitability in two task-specific networks, with each source region comprising superficial and deep pyramidal cells, spiny stellate cells and inhibitory interneurons.

Results
In simulations, we found excellent (r=0.8-0.9) and fair (r=0.5-.6) recovery of pyramidal and inhibitory cell excitability parameters, respectively. Across the two auditory paradigms, we found that reduced paired-click and P300 responses in B1 were explained by both pyramidal and inhibitory cell dysfunction. Conversely, B2 showed impaired pyramidal and B3 impaired inhibitory cell function only. We found that more severe cognitive symptoms correlated significantly with reduced pyramidal cell excitability across both paradigms.

Conclusions
Our findings suggest that E/I balance is impaired in psychotic disorders and that different transdiagnostic biotypes map onto different cell dysfunctions, specifically to an E & I (B1), an E (B2) and an I (B3) biotype. This modelling approach could be used to probe cell function non-invasively with OPMs in the future and identify appropriate drug targets on excitatory

and inhibitory cells for targeted glutamatergic interventions in patients with psychotic disorders.

Key words: oddball paradigm, paired-click paradigm, dynamic causal modelling, interneuron, pyramidal cell, excitation/inhibition balance

20 - Oral Presentation

Brain anatomy and molecular signaling predict neurophysiological dynamics

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Brain activity is shaped and constrained by the underlying anatomy and organization, which form the foundation for human cognition and behavior. However, the precise nature of this relationship remains unclear. Here, we present a nuanced approach to investigate the extent to which resting-state activity can be explained by structural and neurochemical features. What are the most important predictive features, and which aspects of brain signals do they change?

Using openly available data from the Cambridge Center for Ageing and Neuroscience, we computed power spectra (1-60 Hz) for 350 individuals (18-88 years) measured using magnetoencephalography (MEG). Five minutes of data were used after regressing out the effects of age, sex, and intracranial volume. We applied partial least squares regression (PLSR) and 10-fold cross-validation to predict the averaged power spectrum in 200 brain areas from 55 brain maps (neuromaps: Markello et al., 2022, Nat Meth; enigma toolbox: Larivière et al., 2021, Nat Meth). Spherical rotations of these maps (spin-test with 1,000 permutations) were used to generate a null distribution and assess statistical significance. We then applied stepwise PLSR starting from the most predictive map and iteratively added indicative maps to test at how many features model accuracy peaks.

Our model predicted regional differences in power spectra with high accuracy ($R2 = 0.83$, $pspin < 0.05$). Key predictors included mean neuronal density, opioid, dopaminergic, acetylcholinergic, serotonergic, and GABAergic receptor distributions, along with the principal component of gene expression. Incremental regressions revealed that the spatial and biological information from around 20 maps sufficed to accurately explain functional variability in the power spectrum.

These results suggest that a substantial portion of cortical variation in brain activity during rest is governed by specific microstructural and neurochemical distributions. Critically, uncovering this link will deepen our understanding of neuronal dynamics and lay the groundwork for exploring how these key features may underlie cognition or clinical disorders.

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21 - Poster

A Framework for Uncertainty Calibration in M/EEG Source Imaging

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Magneto- and electroencephalography (M/EEG) are indispensable, non-invasive tools for monitoring brain activity, with clinical uses (e.g., surgical planning for drug-resistant epilepsy) that demand precise source localization. Inverting the mapping from neuronal currents to sensors is severely ill-posed and noise-sensitive; prior assumptions and noise levels critically shape the estimates. Despite this, most brain source imaging (BSI) methods report only point estimates, whereas calibrated uncertainty is essential for high-stakes decisions. We address this gap by focusing on uncertainty quantification (UQ) and uncertainty calibration (UC) for linear M/EEG inverse problems.

We introduce a simulation-based benchmarking framework that jointly evaluates reconstruction accuracy and uncertainty calibration. Treating source reconstruction as regression on current vectors, we quantify uncertainty for both amplitudes and orientations via dimension-matched credible regions: (i) credible intervals (1D) for fixed-orientation models; (ii) credible ellipses (2D) for MEG after tangential projection; and (iii) credible ellipsoids (3D) for EEG in free-orientation settings. These regions enable coverage-based UC metrics and provide geometrically interpretable visualizations of uncertainty in magnitudes and orientations.

We benchmark classical and Bayesian estimators that yield Gaussian posteriors, including eLORETA, Bayesian minimum-norm, and sparse Bayesian learning (SBL) methods such as gamma-MAP. We also compare strategies for setting regularization and noise/prior hyperparameters (cross-validation, joint source/noise covariance estimation) and analyze their impact on UC.

Our study reveals critical limitations of current BSI posteriors for UQ. Zero-mean shrinkage priors bias posterior means toward zero, underestimating true source amplitudes (overshrinkage). In gamma-MAP (Type-II empirical Bayes), hyperparameters are fixed at the marginal-likelihood maximizer, ignoring hyperparameter uncertainty and promoting pruning. Inactive sources then receive degenerate (zero) posterior variances, precluding meaningful UQ and yielding underestimation of uncertainty around retained sources. To mitigate degeneracy, we adopt posterior models with non-degenerate, spatially extended support using sparse basis field expansions, an extension of scalar Gaussian basis functions supports credible intervals near inactive regions.

Empirically, we observe complementary pathologies: gamma-MAP tends to be underconfident (intervals are too wide); (ii) linear dense estimators such as eLORETA can be overconfident (intervals are too narrow). These findings motivate principled uncertainty calibration. Finally, we apply post-hoc isotonic regression to recalibrate nominal credible levels against empirical coverage, correcting systematic miscalibration and yielding posterior credibility that better matches observed frequencies.

Well-calibrated uncertainty is a key prerequisite for reliable M/EEG use in critical applications, yet it is not addressed by existing methods. This work provides an objective assessment framework and uses it to benchmark the UC of methods that produce Gaussian posteriors.

22 - Oral Presentation

The influence of Lorazepam on neuronal oscillations and temporal perception

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Studies have demonstrated a correlation between the temporal resolution of perception and neuronal oscillations. Specifically, the frequency with the most prominent peak in the spectrum, i.e., the peak frequency (PF), is thought to define a temporal binding window for perception. Most of the supporting evidence comes from research in the visual domain, particularly examining parieto-occipital PF. However, evidence from other sensory modalities remains limited. Furthermore, the existing evidence linking PF to perception is primarily correlative in nature.
The present study aimed to investigate a potential causal relationship between PF and perception. To achieve this, we sought to modulate PF of neuronal oscillations through the administration of lorazepam, a GABAa-receptor agonist known to reduce PF in neuronal oscillations. In a double-blind protocol, participants completed three sessions in which they were administered either 0.5 mg, 1.5 mg lorazepam, or a placebo. During these sessions, participants performed a tactile temporal discrimination task while neural activity was recorded using magnetoencephalography (MEG). We hypothesized that lorazepam impairs tactile temporal perception and decreases PF in somatosensory areas.
Results indicate that – in line with the hypothesis - lorazepam impaired participants' performance on the tactile discrimination task. In addition, lorazepam altered PF and power of neural oscillations. In contrast to our hypothesis, however, a negative correlation between temporal resolution and PF was observed in the alpha band (~8-12 Hz) in parieto-occipital regions, but not in somatosensory regions.
In summary, these findings provide preliminary evidence supporting a causal link between lorazepam and neuronal oscillations on the one hand and PF and temporal perception on the other hand. Future analyses will further study the impact of lorazepam on PF across the entire brain.

23 - Poster

Investigating the excitation/inhibition ratio in the healthy and pathophysiological brain and its effect on temporal discrimination

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Neural activity exhibits periodic and aperiodic patterns. While numerous studies have studied the role of the periodic neural activity, only recently research has focused on a potential role of aperiodic activity for perception and cognition. The aperiodic pattern is characterized by an exponential decay of spectral power with increasing frequency (1/f pattern). The specific form of 1/f pattern is tightly linked to an excitation-to-inhibition (E:I) balance of neurons or neural circuits.
The E:I ratio may be pathologically altered in several diseases (e.g., Parkinson's disease, Schizophrenia). Thus, studying E:I ratio through analysing aperiodic activity may be a useful tool to understand pathological brain activity.
In the present study, we measured neural activity with MEG in 17 healthy participants and 17 patients with hepatic encephalopathy (HE), while participants performed visual and temporal discrimination tasks. HE is characterized by elevated ammonia levels, which are known to affect the brain's inhibitory system via altered GABAergic levels. Since GABA is the main neurotransmitter for inhibitory neural activity, we hypothesized that aperiodic activity should be altered in HE patients. Furthermore, HE patients are impaired in their temporal discrimination ability. Therefore, we studied whether aperiodic activity correlates with temporal resolution of patients and controls.
We found that HE patients show significantly lower aperiodic exponents in parieto-occipital regions ($p < .01$) and a trend towards significance for higher exponents in frontal regions ($p = .085$). In addition, we found that aperiodic activity correlates with temporal discrimination: in parieto-occipital regions, higher exponents indicated better temporal resolution in both the visual and the tactile discrimination task ($p < .05$). Conversely. in frontal regions higher exponents correlated with worse temporal resolution ($p < .05$).
In sum, analysis of aperiodic activity with MEG provides a useful tool to study E:I balance in the healthy and pathological brain. In addition, we demonstrate that these E:I levels correlate with temporal discrimination abilities.

24 - Poster

Attentional modulation of initial sensory processing in the human spinal cord

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The physiology of the human spinal cord has long eluded direct investigation. Based on recordings of electric potentials via electroencephalography (EEG) electrodes placed around the neck, we have recently shown that temporal expectation modulates high-frequency signals induced at around 600 Hz within 13-16 ms after electric stimulation of the median nerve, in line with a neural generator in the spinal cord (Stenner et al., Science Advances 2025). Here, we show that intermodal attention also changes high-frequency signals at these latencies. Across two groups of healthy individuals (n=30 each), we presented a train of median nerve stimulation, concurrently to a train of auditory beeps, each consisting of stimuli predominantly separated by irregular, i.e., inconsistent, inter-stimulus intervals. Participants were asked to detect transient temporal regularities (four to five consecutive stimuli presented with regular, i.e., constant, inter-stimulus intervals) in one sensory modality while ignoring the other modality. Behavioural responses, as well as somatosensory evoked potentials in scalp EEG, confirmed that participants were shifting attention to the currently task-relevant modality. Importantly, we also found preliminary evidence of attentional modulation of the power of 400-1000 Hz signals induced in neck recordings between 10 and 16 ms after median nerve stimulation. The polarity of this modulation pointed to a spatial lateralization of the effect according the stimulated body side. The concurrent short-latency somatosensory evoked potentials, on the other hand, did not reveal any attentional modulation. Our preliminary findings suggest that attention operates at initial stages of somatosensory processing in the spinal cord, evident in high-frequency signals, but not the evoked response. These findings are highly relevant for future OPM-MEG applications, such as the recently introduced OPM-magnetospinoencephalography (Mardell et al., J Neurosci Meth 2024).

25 - Poster

OPM-MEG for functional mapping

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Introduction

Whole-head OPM-MEG systems have started becoming more widespread in recent years but are so far mostly used for research despite their expected advantages over SQUID-MEG. A few studies have hinted at the potential of OPM-MEG for clinical use but have mostly used smaller systems with limited coverage or looked at small number of subjects. Here we benchmark OPM-MEG against SQUID-MEG to determine its suitability for functional mapping and other clinical applications.

Methods

We recorded 15 healthy participants in a single session with both OPM- and SQUID-MEG inside the same magnetically shielded room. OPM-MEG was recorded with a 128-sensor HEDSCAN from Fieldline Inc. (Boulder, CO, USA), SQUID-MEG with a 306-ch TRIUX from MEGIN Oy (Helsinki, Finland). The same HPI-coils in combination with Polhemus head digitization were used to co-register the recordings to an anatomical MRI for source reconstruction.

To compare both systems at their best performance, we ran the SQUID-MEG with internal activate shielding and processed the recordings with tSSS. For the OPM-MEG recording internal active shielding was disabled as it increased noise at the location of the OPM sensor array. That recording was processed with 1st-order homogenous field correction.

Same paradigms were run in OPM- and SQUID-MEG including: 1) tactile stimulation of 5 phalanges of the index finger and thumb, and 2) an auditory oddball task with two oddballs and frequency-tagged tones, used for functional mapping. We looked at the early somatosensory activity (M60) in task 1 and compare them on sensor and source level (dipole fits and minimum norm estimates (MNE)).

Results

We observed similar sensor signal patterns with no signifiacnt differences in peak latencies and ~2.7x higher amplitudes in OPM-MEG compared to SQUID-MEG. Despite higher sensor noise, signal-to-noise-ratio in the OPM-MEG data was higher (~1.3x) compared to SQUID-MEG.
Dipole fits showed a significantly lower spread (~1/2.5) for OPM-MEG between the different phalanges – which are expected to activate closeby sources. The average distance between the SQUID and OPM fits were 12 mm, approximately 2 times larger than the distance between SQUID-MAG and SQUID-GRAD dipoles, which may be due to differences in the co-registration. MNE source distributions showed a sharper activation area and significantly higher overlap with the postcentral region where the activation is expected.

Conclusion

The combination of enhanced sensitivity, higher signal-to-noise ratio, and more clearly defined source localization suggests that OPM-MEG is well suited for functional brain mapping.

26 - Oral Presentation

Key Metrics for Commercial SERF-OPM Multichannel Systems

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Spin-Exchange-Relaxation-Free (SERF) Optically Pumped Magnetometers (OPMs), ranging from single-sensors to fully integrated multichannel systems (MCS), have opened new frontiers in biomedical applications and other sensing areas through remote and rapid magnetic field sensing. Signal integrity and optimal performance of an MCS are achieved only when all channels exhibit nearly identical characteristics, namely: gain, amplitude response, timing effects, stability, directivity, and linear range. Currently, studies need to characterize the non-ideal behavior of SERF-OPM multichannel systems until manufacturers provide extensive and standardized specification sheets. Additionally, pilot simulation studies must be performed to investigate the influence of imperfect sensor responses on typical biomagnetic signals before OPM systems can be considered for clinical use cases.

We demonstrate a systematic approach for characterizing highly-sensitive magnetometers within the Berlin Magnetically Shielded Room 2.1 (BMSR-2.1) at the Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany. Central to this effort is our dedicated test bench (DALAC), which facilitates detailed assessment of key performance parameters within a well-characterized test environment and magnetic test field[1]. Key parameters are introduced using commercially available multichannel SERF-OPM systems, in comparison with the biomagnetic gold standard given, SQUID.

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1 E. Elzenheimer, S. Knappe-Grüneberg et al., *Key Metrics and Experimental Test Bench for Assessing Highly Sensitive Magnetometers in Research*, IEEE Sensors, vol. 25, no. 2, pp. 2432-2455, 2025.

27 - Poster

Physical Activity Improves Cognitive Processes by Altering Brain State

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Physical activity (PA) has long been linked to enhanced cognition, yet the underlying neurophysiological mechanisms remain unclear. We investigated the acute effects of PA on visual attention and working memory (WM) using a Magnetoencephalography (MEG)-compatible pedal trainer that enabled combined MEG and Electroencephalography (EEG) recordings immediately after PA. Before each experimental block, participants either pedaled at a moderate pace or rested for 2 minutes.

To assess attention, participants performed a starry night paradigm in which a spatial cue reset theta phase and a target grating appeared after variable delays. Behavioral performance oscillated rhythmically in the theta band, and this rhythmicity was amplified following PA. Neurally, PA enhanced theta-band modulation of occipital high-frequency activity (HFA; 80–150 Hz) and strengthened HFA–behavior correlations, reflecting more efficient sensory encoding.

In the WM experiment, participants performed an N-back task. MEG revealed medial temporal lobe (MTL) ripple events that correlated with WM accuracy and showed stronger memory-load dependence post-PA. Concurrently, frontal EEG detected wake spindle activity, and ripple–spindle coupling was strengthened, indicating that PA transiently modulates WM.

Together, these results demonstrate that acute PA induces transient brain state changes that optimize cognition via frequency-specific mechanisms: ripple–spindle coupling for WM and theta-driven HFA modulation for attention. This mechanistic link between motor and cognitive systems suggests that even brief bouts of walking or cycling can dynamically enhance memory and attention in real-world contexts.

28 - Poster

Physical activity modulates early visual response and improves target detection in humans

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Brain state changes affect visual perception by altering spatial resolution. Attention enhances the spatial resolution decorrelating neuronal activity in early nonhuman primate (NHP) visual cortex. Physical activity (PA) amplifies these attentional effects in rodents but impact of PA on visual perception in humans remains uncertain. We investigated the relationship between broadband high-frequency activity (BHA: 80-150 Hz) recorded with magnetoencephalography (MEG) and visual detection performance. We found that PA enhanced visual target detection predicted by a reduction of early BHA responses (<90 msec). This effect may be due to reduced interneuronal correlation to improve spatial resolution. Moreover, PA improved spatial integration time, as indicated by a linear relationship between reaction times and BHA variation with target eccentricity. These findings provide evidence that PA influences neuronal activity critical for early visual perception, optimizing visual processing at the initial stages of the visual hierarchy.

29 - Poster

Causal inference can explain postdictive multisensory illusions

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Information from different sensory modalities is integrated in a temporal window of multisensory processing that can last several hundred milliseconds. Within this window, the processing of a stimulus is influenced not only by preceding and concurrent input, but also by input following a stimulus. A previous study using a beep-flash pair showed that auditory or visual stimuli presented shortly after a stimulus can retroactively influence the perception of the first stimulus, resulting in an illusory or invisible flash (Stiles et al., 2018; PloS One 13:e0204217). A single beep presented between two flash-beep pairs can induce an illusory flash, whereas a single flash presented between two flash-beep pairs can be perceptually suppressed. In the behavioral study, we used a Bayesian Causal Inference (BCI) framework to investigate the mechanisms underlying the two multisensory postdictive illusions. We replicated both illusions, found that asynchronous stimuli that fall outside the temporal integration window reduce the illusions, and that the causal inference framework can largely explain cross-modal postdiction better than competing forced-fusion and forced-segregation models. In addition, we present preliminary data from a follow-up EEG study that offer new insight into the neural mechanisms of the observed multisensory postdictive illusions.