WEDNESDAY, JUNE 8

8:50 – 9 • Conference Opening

9 – 10:30 • Oral Session: Hardware

Methods for assessing artifact susceptibility and mitigation

David Hairston (NIL) {*william.d.hairston4.civ@mail.mil*}

Collecting data targeting neural responses to real-world phenomena often involves head and/or body movements that can easily contaminate electrical signals. As a result the community has adopted a myriad better data acquisition methods, ranging from novel hardware approaches to online and post-processing methods. However it is still critical to quantify the noise susceptibility of any new method to understand what can be expected. In this talk I will review our recent work in developing means for assessing the extent of artifact susceptibility of electrical neuroimaging, specifically with paradigms that create known motion profiles and artifacts. Examples includes the development and validation of surrogate "phantom" heads in combination with motion platforms to use as a ground truth, creation of artificial signals on the scalp, and using as a set of motion-inducing scenarios with human subjects in VR.

Integrating Immersive VR for MoBI research

Lukas Gehrke (TU Berlin) {*lukas.gehrke@tu-berlin.de*}

Running MoBI experiments is a resource intensive endeavour, often requiring large lab spaces with intricate setups for stimulus presentation. One way to decrease the strain on available resources is to leverage immersive, head-mounted, virtual reality (VR) setups. Their key promise are reliable and easy-to-control experimental environments. These often come a lower implementation cost.

However, many challenges remain in combining high density EEG recordings with VR setups. Challenges range from artefact contaminated signals to ergonomic issues. In this talk, I will first review our work leveraging VR setups for MoBI research in light of these challenges.

In the second part of the talk, I will then present our research on the contribution of different sensory modalities to the feeling of immersion in VR serving as one example of the research questions that can be addressed by combining MoBI and VR.

Aesthetics in the Wild: An EEG and Eye Tracking Study of Viewer Engagement at the San Diego Museum of Art

Ying Choon Wu (UC San Diego) {*yingchoon@gmail.com*}

Many existing cognitive models of aesthetic experience have been criticized for building from the assumption of an isolated, de-contextualized encounter with a piece of art and for adopting research methods that treat unique and varied artworks as equivalent stimuli. In line with this criticism, work by Brieber et al has demonstrated that context modulates aesthetic engagement, with artworks on display in a museum eliciting longer viewing times, higher interest ratings, and superior recall relative to the same items viewed in a lab. This talk examines research and methods aligned with this growing focus on situated and contextualized experiences of art. In partnership with the San Diego Museum of Art, electroencephalographic and eye tracking data were recorded as healthy adults viewed an eclectic mix of paintings on display in the Gallery of the Americas. Afterwards, the same paintings were revisited, and a Likert scale was used to rate various aesthetic emotions elicited during the viewing phase by each one (e.g., fascination, calmness, indifference, surprise, amusement), allowing arousal scores to be derived for each painting. Variability between individual's fixation-related potential (FRP) responses and gaze patterns as a function of arousal was observed. For some individuals – classified as strong responders – overall viewing times tended to increase dramatically with arousal, whereas for others – labeled weak responders – viewing times increased with arousal to a much lesser extent. Comparisons between these two groups revealed a number of differences in gaze patterns. Strong responders, for instance, tended to make longer fixations with smaller saccadic amplitudes than weak responders, consistent with a more focally dominated viewing strategy. Preliminary FRP analysis suggests that arousal may modulate semantic processing as well. Implications of these outcomes for curatorial practice will be discussed.

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10:45 – 12:15 • Oral Session: Software

New developments in the NEMAR Open Neuro gateway for EEG

Arnaud Delorme (UCSD) {*arnodelorme@gmail.com*}

To take advantage of recent and ongoing advances in large-scale computational methods, and to preserve the scientific data created by publicly funded research projects, data archives must be created as well as standards for specifying, identifying, and annotating deposited data. The openneuro.org archive, begun as a repository for magnetic resonance imaging (MRI) data, is such an archive. We present a gateway to OpenNeuro for human electrophysiology data (BIDS-formatted EEG and MEG, as well as intracranial data). The NEMAR gateway allows users to visualize electrophysiological data, including time-domain and frequency-domain dynamics time-locked to sets of experimental events recorded using BIDS- and HED-formatted data annotation. In addition, NEMAR allows users to process archived EEG data on the XSEDE high-performance resources at SDSC in conjunction with the Neuroscience Gateway (nemar.org), a freely available and easy to use the portal to leverage high-performance computing resources for neuroscience research.

Hierarchical Event Descriptors for multimodal brain imaging

Dung Truong (Swartz Center for Computational Neuroscience) {*dt.young112@gmail.com*}

Information about experiment events are crucial in the analysis of neuroimaging data. We want to know not only what happened and when, but also the relationships between events with respect to their temporal structure and experiment design. The Hierarchical Event Descriptor (HED) system standardizes the annotation of experiment events and other data features in a format that is both human-readable and machine-actionable. We will give an introduction to HED and its use in annotating multimodal data. We will demonstrate how HED works with the Brain Imaging Data Structure (BIDS) to enhance the usability of shared datasets. We will also discuss current and planned future support for HED in the extension of BIDS for motion capture.

MoBI data analysis made easy – The BeMoBIL Pipeline

Marius Klug (TU Berlin)*; Klaus Gramann (TU Berlin) *{*marius.klug@tu-berlin.de*}

Multimodal data analysis of high-density electroencephalography (EEG), motion capture (MoCap), and other physiological measures like eye-tracking in Mobile Brain/Body Imaging (MoBI; Makeig et al., 2009; Gramann et al., 2011: 2014) setups can be a challenging task. Different software packages exist to help researchers accomplish their goal of sound and reproducible data analyses, however, a comprehensive pipeline which ties together established MoBI processing steps is currently missing. A plethora of decisions have to be made regarding order of processing or choice of parameters, often including manual cleaning and selection, proposing challenges with regards to reporting, reproducibility and validity of research outcomes.

To facilitate this process, the "BeMoBIL-pipeline" was created, establishing a comprehensive analysis pipeline for all steps from importing the raw multimodal data sets (e.g. in Extensible Data Format – XDF) to a clean EEG data set that allows for computing final measures of interest (e.g. ERPs). It makes use of existing EEGLAB packages by easy-to-use wrapper functions and includes new functions for automated processing. The package comprises scripts and wrappers for MoCap data analysis, event creation from movement and other data streams, preprocessing in EEGLAB, automatic channel rejection, re-referencing, filtering, automatic artifact cleaning, independent component analysis, component rejection, and an algorithm for repeated k-means clustering of independent components on the study-level in order to increase reproducibility. All functions store their parameters in the data structure which makes reporting the analysis pipeline straightforward. Additionally, many steps include comprehensive analysis plots which can be used to inspect the efficacy of the pipeline at any stage. Default parameters and guidelines exist. Finally, meta wrapper functions allow running the entire pipeline for all subjects after choosing relevant parameters.

The repository can be downloaded at https://github.com/BeMoBIL/bemobil-pipeline.

Characterizing and Removing Artifacts using Dual-Layer EEG during Table Tennis

Amanda Studnicki (University of Florida)*; Daniel P Ferris (University of Florida) *{*astudnicki@ufl.edu*}

Motivation: Ecological valid, real-world conditions are necessary to study neural correlates of natural cognition [1]. Maintaining high-fidelity signals in mobile conditions is challenging due to physiological and non-physiological artifacts. Some approaches to reduce artifacts use reference noise signals, such as separate electro-oculogram (EOG) channels, neck electromyography (EMG) channels, or head movement measured with inertial measurement units (IMU), to aid in signal processing [2]–[4]. In the dual-layer approach to EEG, noise channels provide an alternative representation of motion artifact than head acceleration or rotation [5]–[7]. Noise channels are electrically isolated and mechanically coupled to scalp channels which may include more of the cable-induced artifact than other reference noise signal sensors. Many mobile EEG studies that characterize noise use gait-related experimental paradigms (i.e., walking or running) [4], [8], [9], while fewer studies characterize noise in non-gait-related tasks. Table tennis may be a useful sport to investigate visuomotor feedback, anticipation, object interception. Players use their whole bodies to move and hit the ball, and their rotational movements may induce different artifacts than locomotion. The purpose of this study was to characterize and identify strategies to remove artifacts in EEG data for a discrete, responsive, whole-body task such as table tennis.

Methods: Participants (n=20) wore a high-density dual-electrode EEG cap made up of 120 scalp electrodes and 120 noise electrodes. Eight of the original 128 scalp electrodes were re-purposed to measure neck muscle activity. We placed inertial measurement units on a table tennis table, net, ball machine, and on the handles of two wooden paddles to mark event timing. For the last four participants, we placed an inertial measurement on the participant's forehead to measure head movement. Participants played table tennis with a ball machine and human player, broken into four 15-minute blocks. Trials involved cooperative or competitive play with a human player, or stationary or moving hitting with the ball machine.

First, we compared power spectral densities, event-related spectral perturbations, and time series correlations of reference noise sensors and scalp electrodes to characterize artifacts. Then, we employed four different pipelines to compare artifact removal strategies. The Minimal pipeline included basic pre-processing (filtering, channel rejection and interpolation, average re-referencing). The Minimal & Time Reject pipeline rejected bad time windows using clean_artifacts after minimal cleaning. The Minimal, 3 Hz & Time Reject pipeline filtered the scalp channels after minimal cleaning and with subsequent time window rejection (substituting for iCanClean). The Minimal, 120iCan & Time Reject pipeline applied canonical correlation analysis in a 2-second sliding window to find subspaces of the 120 scalp electrodes that were strongly correlated with subspaces of the 120 noise electrodes. For each pipeline, we applied independent component analysis. The weight matrix from each pipeline was applied to the dataset from the Minimal pipeline to ensure a fair comparison. We fit each independent component to an equivalent dipole using DIPFIT3.3. To objectively measure the quality of the decomposition, we computed a dipolarity metric as the number of components with residual variance less than 15% [10]. We also computed the number of brain components that the ICLabel plug-in [11] classified with a brain probability of greater or equal to 75%.

Results: The shapes of the power spectral density plots varied by sensor type. The noise electrodes exhibited higher power in low frequencies and their slope was steeper than the other sensors. Scalp electrodes had a similar 1/f curve but had an increase in power in the alpha and beta frequency range, most noticeable in the standing baseline condition. The mobile hitting conditions had more power in higher frequencies. All sensor types and hitting conditions showed statistically significant time-frequency pixel changes in power compared to the standing baseline condition. The noise electrodes' change in power was consistent across electrode locations and were concentrated in low frequencies around the hit event. The increase in power was more diffuse across the swing cycle in the moving and competitive than stationary and cooperative conditions. The scalp electrodes show a similar pattern of spectral power increase around the hit event that is more diffuse in the moving and competitive conditions. However, FCz and C5 scalp electrodes also exhibit alpha desynchronization relative to standing baseline that was not present on any reference noise sensor. The Pearson r correlation between individual scalp channels and the other sensors varied by electrode location. Muscle channels correlated most with scalp channels at the back and sides of the head. The scalp electrodes correlated less with the body and head IMUs than the noise-matched electrodes. The body and head IMU correlation with the scalp electrodes showed a similar increase in the four hitting conditions compared to the standing baseline condition.

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Overall, the Minimal, 120iCan & Time Reject pipeline outperformed the other cleaning pipelines. On average, the Minimal, 120iCan & Time Reject pipeline resulted in 15 more components that passed the dipolarity threshold of <15% residual variance compared to the Minimal and Minimal & Time Reject pipelines. The Minimal, 3 Hz & Time Reject pipeline had a similar number of dipolar components, although slightly less than the Minimal, 120iCan & Time Reject pipeline.

Implications: Understanding the neural correlates of natural movement under ecologically valid conditions is important. This study advances techniques for mobile brain imaging by analyzing artifact in a whole-body, responsive task. We found that the dual-layer approach does well to characterize and remove motion artifact affecting scalp channels during a dynamic sport like table tennis.

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ICMOBI: A MoBI extension to ICLabel

Noelle Jacobsen (University of Florida)*; Daniel P Ferris (University of Florida); Klaus Gramann (TU Berlin); Julie Han (University of Florida); Marius Klug (TU Berlin) *{*jacobsen.noelle@ufl.edu*}

Electroencephalography (EEG) is becoming a powerful tool for mobile brain imaging research because it enables real-time, noninvasive monitoring of electrical brain activity with high temporal resolution. EEG acquired during active human motion is usually contaminated with a variety of unwanted signals such as muscle, eye, and cardiac signals that have to be separated from the signal of interest. Independent component analysis (ICA) is one method that can be used to separate brain activity from high-amplitude motion and muscle artifacts. Independent components found using ICA can be visually inspected, selected, and interpreted, but this requires extensive time and expertise. Alternatively, automated classifiers can be used to broadly categorize independent components, reducing time spent analyzing EEG data and increasing replicability across research labs. While many such classifiers have been developed [1-7], their underlying models rely on stationary EEG data, which does not fully represent the data content of mobile EEG studies. Our objective is to design a classifier using data from mobile EEG recordings that will automatically categorize neural and artificial components. We hypothesize that a classifier trained on mobile EEG data will improve the accuracy of independent component label estimates when compared to the best publicly available automated independent component classification method.

We are collecting a training set of mobile EEG data that will be used to train the classifier. We invite researchers to submit their MoBI datasets to contribute to training a robust classifier (see further project details here: https://faculty.eng.ufl.edu/human-neuromechanics-laboratory/projects/). To increase robustness, we aim at including datasets from many labs with a wide range of experimental protocols. All data sets should contain human subjects performing tasks with whole body movement with a minimum channel density of 64 electrodes for more accurate source localization [8,9]. Other inclusion criteria include participants that are neurologically intact, older than 12 years of age, and have normal or corrected to normal vision. Studies that include participants with neurological or locomotor (muscular/musculoskeletal) deficits (e.g., Parkinson's disease, multiple sclerosis, post-stroke hemiparesis, spinal cord injury, cerebral palsy) will be excluded. Further requirements for the data to be included can be found on the project website.

We will use an artificial neural network (ANN) to develop our ICMoBI (Independent Components of Mobile Brain Imaging) classifier as they are particularly useful for complex pattern recognition and classification. Supervised training of this classifier requires a training set of ICs that have corresponding labels. To create this training set, we will be collecting IC labels from users on the ICMobI website, which will be our crowd labeling platform, similar to Pion-Tonachini et al. (2019)[5].To train our classifier, we will select features that will capture both spatial and temporal characteristics of each component: scalp topography, dipole location, power spectra, cross-frequency power coupling, as well as time-domain features (root-mean square, mean absolute value, waveform length, variance, standard deviation). Principal component analysis will be used to reduce the dimensionality of the feature set. The classifier hyperparameters will be tuned using 10-fold cross validation on the training set. Classifier performance will be evaluated using an expert-labeled test set built using datasets that were not included in the training set (i.e., the IC's used for training and testing were from different ICA decompositions).

Our goal in creating this classifier is to reduce component analysis time and subjectivity in component selection for researchers involved in mobile EEG research and to extend the range of existing IC-labels from stationary protocols to a wider range of IC-labels, including movement-related ICs as reported in previous MoBI studies [10]. Preliminary results will be presented at MOBI 2022.

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1:30 – 2:30 • KEYNOTE: Scott Makeig (UCSD)

Mobile Brain/Body Imaging of Social, Affective, and Creative Agency

Affective expression, perception, and communication -- including aesthetic and artistic perception -- gives a sense of value and meaning to our life, as well as organizing our behavior. Our extensive brain sub-system supporting affective perception, awareness, and behavior has evolved in parallel with brain systems supporting physical perception and awareness of our environment and our behavioral interactions with it. Our affective perception and communication systems may largely operate outside our focus of explicit attention. Yet their functioning is crucial to making everyday decisions and interacting with others. In particular, our capacities for feeling and expressing empathy and compassion are essential to our development and maintenance of social relationships -- within family, community, and society.

I believe the evolutionary basis of our aesthetic perception and appreciation, and thus all human artistic activities, has arisen from our basic need to continually discern ***what others around us are feeling***. We have many personal, social, and culturally-promoted reasons to 'hide our feelings' from one another. Yet emotional state and its behavioral expression are our best clues to the intent and future actions of others, and thus are our best guide in choosing how to interact with them. Our affective perception system is always 'on,' always attempting to interpret our experience in terms of ***human feeling character***. Thus, as perceived through the lens of our affective perception, a bird's flight may appear to us 'exhilarating,' a sudden car honk 'indignant,' the flowing lines of a garment 'seductive,' an orchestral horn flourish 'triumphant,' etc.. It is our seemingly 'invisible' but 'felt' brain system supporting affective perception of the feelings of others that makes possible and supports human artistic perception, communication, enjoyment, and activity.

How to perform brain/body imaging of authentic affective and artistic experience and expression? A most difficult and far too often ignored or undervalued task here is to design and execute experimental protocols that capture periods, even brief, in which authentic affective experience, expression, and communication ***dominate*** a participant's experience. Empathic psychotherapists, nurses, teachers, and parents know much about how to develop sufficient trust to enable others to attend empathically and to express authentic feelings in their company. A useful observation is that hypnotized subjects tend to have unusually strong and ready access to affective experience. Effective protocols to record MoBI data in which brain and body movement dynamics supporting affective perception and communication dominate may thus benefit from using guided imagery methods that approach self-hypnosis. Using such methods can allow and encourage participants to experience and express deep, authentic feeling during brain/body imaging experiments. The same difficulties apply to experiments involving artistic experience and expression. The ability to induce intense affective experience in others through music or dance performance, graphic design -- that is, to exercise ***affective agency*** -- is rare, and all societies celebrate the relatively few artists who achieve this most effectively. Capturing MoBI data during such authentic artistic expression and experience is not a matter of luck; it is a goal that can only be achieved through careful design of suitable protocols and a deliberate personal approach.

BIOGRAPHY: **Scott Makeig** completed a Bachelors degree, 'Self in Experience' at the University of California Berkeley in 1972, a Masters in Music Theory (abt) at the University of South Carolina in 1979, and a Ph.D., 'Music Psychobiology,' from the University of California San Diego (UCSD) in 1985. After a year in Ahmednagar, India as an American India Foundation research fellow, he became a research psychobiologist at the UCSD Department of Psychiatry and then at the Naval Health Research Center, San Diego. In 1999, he moved to the Salk Institute, La Jolla, and then in 2001 to UCSD as a Research Scientist to develop and direct the Swartz Center for Computational Neuroscience (SCCN, *sccn.ucsd.edu*).

His primary research interests are in developing and applying high-resolution 3-D functional EEG imaging and analysis to high-density EEG and iEEG data and to concurrent, high-density human EEG and biobehavioral data, a modality he termed mobile brain/body imaging (MoBI) in 2009. He and colleagues pioneered the use of time/frequency and independent component analysis (ICA) in EEG and biomedical signal processing and continue

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to develop and support the widely used open source EEGLAB software environment for electrophysiological signal processing (*sccn.ucsd.edu/eeglab*). Currently, he and colleagues, in collaboration with the San Diego Supercomputer Center are building an integrated data, tools, and compute resource, NEMAR, that marries neuroimaging data contributed to OpenNeuro (*openneuro.org*) with NSF-supported high-performance computing resources via the Neuroscience Gateway (*nsgportal.org*), and are developing an ecosystem of specifications and tools for the Hierarchical Event Descriptor (HED) system for event annotation of time series data.

2:30 – 3:30 • Sponsor Equipment Demos

Presentations Introducing subsequent demos (continuous throughout poster session)

3:30 – 6 • Poster Session

Poster Abstracts contained in a separate document.

THURSDAY, JUNE 9

9 – 10:30 • Oral session: Gait (basic research)

Visual Occlusions Result in Phase Synchrony Across Multiple Brain Regions Involved in Sensory Processing

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There is a need to develop appropriate balance training interventions to minimize the risk of falls as they constitute a public health concern with high socioeconomic consequences. Recently, we found that intermittent visual occlusions can substantially improve the effectiveness and retention of balance training interventions (Symeonidou and Ferris 2022). Therefore, we sought to determine how intermittent visual occlusions affect electrocortical activity when healthy young adults practice beam walking. We hypothesized that sensorimotor brain areas would demonstrate increased electroencephalography (EEG) inter-trial coherence in a wide range of frequencies during loss and subsequent restoration of vision. This would be indicative of cross-modal phase resetting and enhanced sensory processing during the beam walking practice.

Ten healthy young individuals practiced walking on a treadmill-mounted balance beam while wearing high-density EEG and experiencing reoccurring visual occlusions. Independent component and source localization analysis revealed electrocortical clusters in the occipital, temporal, and sensorimotor cortex, areas involved in balance control and sensory processing. We also found clusters in brain areas responsible for controlling the body during walking such as the anterior cingulate and posterior parietal cortex. The onset of the visual occlusion induced increased phase synchrony in multiple electrocortical frequency bands within the posterior parietal and occipital cortices, and in the alpha band within the temporal and anterior cingulate cortices.

Our results provide support for cross-modal phase resetting within cortical areas involved in sensory processing as an explanation for enhanced balance improvement when training with intermittent visual occlusions. Future work will examine a larger number of subjects across a range of ages to determine if there are similar results and enhanced sensory processing using visual occlusions. Long-term, this type of balance training intervention could be easily implemented in senior and rehabilitation centers, improving the quality of life of elderly and neurologically impaired individuals by limiting the consequences of fall-related injuries.

Electrocortical dynamics of perturbed locomotor tasks and a sidebar about the influence of hair types in EEG research

Helen Huang (University of Central Florida) {*hjhuang@ucf.edu*}

Programmable treadmill systems capable of applying a variety of mechanical and visual perturbations have helped move lab-based mobile brain/body imaging studies for understanding cortical control of human locomotion beyond fixed speed treadmill studies. Seated locomotor tasks such as cycling and recumbent stepping, however, have largely been overlooked for understanding the underlying cortical processes involved in human locomotion. Applying perturbations during a range of locomotor tasks such as seated recumbent stepping, fixed speed treadmill walking, and self-paced treadmill walking could help provide a more comprehensive and multi-layered understanding of cortical processes of human locomotion, balance control, and motor adaptation. I will present results using single-layer EEG during perturbed recumbent stepping and dual-layer EEG during perturbed treadmill walking to demonstrate how using a range of perturbed locomotor tasks can identify consistent electrocortical responses that may reveal underlying electrocortical processes of human locomotion and adaptation. In addition, I will briefly highlight survey research that my lab is conducting to investigate the influence of different hair types in EEG research (https://hellobrainlab.com/research/eeg-hair-project/). For mobile brain/body imaging findings to have the desired impact on science, engineering, medicine, and society, it is critical to consider factors such as different hair types that may inadvertently exclude racial and ethnic cohorts of the global population.

Cortical dynamics during locomotion for improved human system integration

Jessica C Bradford (US CCDC ARL) {*jessica.c.bradford.civ@mail.mil*}

Intelligent agents are rapidly becoming more prevalent not only in everyday life but also in current and future technologies for the battlefield. These agents are expected to work as teammates, in conjunction with humans to extend the team capability. A major issue with human agent teaming is how the agents interact with highly dynamic humans. Whether it is computer vision aided target detection, autonomous drones, or physical augmentation devices these technologies must be able to adapt to changes in state or intent of the human without adding burden the human user. One approach for improved teaming between humans and these intelligent agents is to passively monitor the state/intent of the human so that the agents can better understand the human and perhaps interact in a way that takes into account this state, similar to how another human teammate would. In this talk I will discuss how we have been using mobile brain-body imaging (MOBI) approaches to study brain function and track human state during complex operational scenarios, such as loaded ruck marching and learning to walk with robotic physical augmentation. Our goal is to identify biometrics that can robustly track the state of the human in real-time and close the loop between the human and system for improved performance.

Performance and brain dynamics of younger and older adults during dual-task walking

Janna Protzak (TU Berlin)*; Klaus Gramann (TU Berlin) *{*janna.protzak@tu-berlin.de*}

Locomotion is an essential yet complex element of our daily routines. In our everyday live, we navigate, avoid obstacles, and are involved in spontaneous communication with other social agents in the environment. Usually, we handle such multi-tasking situations successfully without the need for significant thought or attention. With advancing age, declines in dual-task abilities can severely impact quality of life and threaten independence. For a better understanding of performance changes in dual-task walking, neurophysiological methods such as electroencephalography (EEG) can provide crucial information about age-related differences in information processing and motor control. Using the MoBI methodology (Makeig et al., 2009; Gramann et al., 2011; 2014), we recently analyzed age-specific allocation strategies in motor resource conflicts (Protzak & Gramann, 2021) and peripheral visual perception (Protzak, Wiczorek & Gramann, 2021) during walking. With our current analysis, we focus on gait cycle-related modulations in brain dynamics (Seeber et al., 2014, 2015) to gain a better understanding of age group difference in postural control mechanisms during gait. In this talk, I will provide an overview of our results from our dual-task walking studies with older and younger adults. Age-related differences in performance and gait data as well as neurophysiological measures and their interdependencies with different levels of motor activity (sitting, standing, walking) will be discussed.

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10:45 – 12:45 • Oral session: Gait (clinical & intervention)

Mobile Brain/Body Imaging (MoBI) for clinical research

Uroš Marušič (Science and research centre Koper) {*uros.marusic@zrs-kp.si*}

Mobile Brain/Body Imaging (MoBI) is an integrative approach developed to study the dynamics of brain and movement. This technique is typically based on mobile electroencephalography synchronized with motion capture to investigate the relationship between brain dynamics, movement, and cognition in most routine movements such as walking, balancing, or learning motor-cognitive tasks. Recently, MoBI has been recognized as a potential application in clinical settings where we aim to determine biomarkers of movement efficiency. In this introductory talk, I will present current protocols currently used in clinical practice and give an example of their value in patients with Parkinson's disease.

Perturbation-evoked cortical response speed during balance recovery biasing paretic and nonparetic lower limbs is associated with weight-bearing asymmetry and walking speed capacity post-stroke

Jacqueline A Palmer (University of Kansas Medical Center)*; Aiden Payne (Florida State University); Jasmine Mirdamadi (Emory University); Lena H Ting (Emory University and Georgia Tech); Michael Borich (Emory University) *{*jpalmer9@kumc.edu*}

Motivation: Older adults increase reliance on the cerebral cortex for postural stability,1,2 which can lead to balance deficits in the presence of brain lesions affecting cortical and subcortical regions, such as after stroke. Greater perturbation-evoked cortical activity over lower-limb sensorimotor cortical regions during balance recovery is associated with lower balance performance in neurotypical younger adults.3,4 However, the role of the evoked cortical activity during balance recovery is poorly understood in older adult populations, particularly in those living with post-stroke balance and walking disability. After stroke, an impaired ability to rapidly and effectively utilize the paretic leg5,6 may bias compensatory utilization of the nonparetic leg for whole-body mobility behaviors such as walking.7 Asymmetrical contributions of the paretic and nonparetic lower limb may contribute to greater deficits in functional mobility after stroke.7 We hypothesized that 1) stroke would have slower and attenuated perturbation-evoked cortical activity during balance recovery biasing the paretic compared to the nonparetic lower limb and compared to neurotypical, age-matched controls and 2) the latency of perturbation-evoked cortical activity during balance recovery would be associated with asymmetry of weight-bearing between paretic and nonparetic lower limbs and clinical walking and balance function after stroke.

Methods: Electroencephalography (EEG) recordings were collected from older adults with (n=18) and without (n=16) chronic (>6mo) stroke during balance recovery from standing postural perturbations. Participants stood on a platform and were subject to posterolateral support-surface translational perturbations that preferentially biased either the paretic leg, the nonparetic leg, or equal legs for balance recovery. We identified cortical activity metrics of onset latency, the peak amplitude, and peak latency of the first robust negative response of the perturbation-evoked cortical activity potential over the leg sensorimotor cortical region (Cz electrode) during the 100-400ms post-perturbation time period of balance recovery. The first negative response was defined as the peak negative amplitude that resumed a consistent upward inflection for at least 50ms.8 We compared perturbation-evoked cortical responses between groups and perturbation conditions. We also tested relationships between perturbation-evoked cortical responses with baseline weight-bearing symmetry of the vertical force vector between limbs ((nonparetic-paretic)/(paretic+nonparetic)), clinical balance function (miniBEST), and walking (10MWT) function in the stroke group.

Results: Regardless of perturbation direction, perturbation-evoked cortical responses in stroke were smaller in amplitude (p=.03) and slower to onset (p=.02) compared to older adults. The slowest onset of the perturbation-evoked cortical response occurred during the perturbation condition that biased paretic leg correction (p=.04). Asymmetry of perturbation-evoked cortical response onset speed between paretic and nonparetic bias conditions were associated with greater baseline weight-bearing asymmetry, in which individuals with slower perturbation-evoked cortical responses during the paretic bias condition utilized greater weight-bearing reliance on the nonparetic limb (r=.82, p=.001). While perturbation-evoked cortical responses during the paretic bias condition were not associated with clinical balance or walking function, slower peak perturbation-evoked cortical responses during the equal limb perturbation condition were associated with lower general clinical balance ability on the miniBEST (r=-.62, p=.02). Slower perturbation-evoked cortical response peaks during the nonparetic bias condition were associated with slower maximal walking speeds (r=-.65, p=.02).

Implications: Our results demonstrate slowed and attenuated perturbation-evoked cortical responses to balance destabilization after stroke that are associated with impaired weight-bearing symmetry and clinical balance and walking function. The relationship between perturbation-evoked cortical response speed symmetry between paretic and nonparetic bias conditions and weight-bearing asymmetry suggests the increased reliance on the nonparetic limb prior to balance destabilization may contribute to slower cortical processing for paretic leg recovery. Alternatively, individuals with slower perturbation-evoked cortical activity during paretic leg recovery may compensate for deficits in cortical processing speed by shifting more weight-bearing reliance to the nonparetic lower limb for standing posture. When biasing the nonparetic leg for balance recovery, individuals with the fastest perturbation-evoked cortical responses had the fastest maximal walking speeds, suggesting that earlier perturbation-evoked cortical activity during nonparetic leg reliance may contribute to effective compensatory strategies that allow some individuals to achieve high ambulatory capacity after stroke.

Together, these findings provide evidence that perturbation-evoked cortical responses elicited during selective biasing of the paretic versus the nonparetic leg for balance recovery reflect differential aspects of post-stroke lower limb dysfunction. Future research could test whether within-session efforts to normalize weight-bearing asymmetry between lower limbs may have immediate effects to accelerate perturbation-evoked cortical responses and paretic neuromuscular reactivity for balance recovery. Future research may also test whether enhancing the speed of perturbation-evoked cortical responses through interventions targeting nonparetic lower limb balance recovery could effectively improve functional walking speed capacity after stroke, particularly in individuals with limited recovery potential of the paretic lower limb.

Electrocortical Activation during Gait and Upper Limb Tasks in Children with Cerebral Palsy

Diane Damiano (National Institutes of Health) {*damianod@cc.nih.gov*}

Background: The longstanding goal of my research is to improve mobility and other aspects of motor function in children with cerebral palsy (CP). CP is the most common child-onset motor disability and results from brain abnormalities or injuries early in development. The resulting motor impairment can be unilateral or bilateral, and mobility (Gross Motor Function Classification System or GMFCS) and hand function (Manual Abilities Classification System or MACS) in these children are typically classified on a Scale from I-V with I indicating mild coordination deficits and V indicating no independent motor abilities. Magnetic resonance imaging techniques (MRI) have been utilized in this population to better understand the underlying brain mechanisms of the motor disability; however, we soon realized that many with CP cannot remain sufficiently still in the MRI due to their motor disorder, and the motor tasks that could be evaluated were greatly limited. Ten years ago, we transitioned from MRI to using mobile brain imaging technologies, including EEG and fNIRS, to study brain activation during a wide range of functional tasks in children with both unilateral (mildest subtype) and bilateral CP (less studied in MRI due to greater involvement). Here we present data from our first EEG study on treadmill gait in unilateral CP (from abstract accepted at MoBI 2020, now published: Short et al., 2020; George et al. 2020), which will also provide a context for the two other studies from our laboratory being presented in this session.

Methods: A total of 20 children participated in this EEG study of treadmill walking: 10 with typical development (TD) and 10 with unilateral CP; mean age =15.0 years in each group. Of those with CP, 6 were GMFCS Level I, 4 were Level II, and 5 each were right and left handed; all with TD were right handed. Treadmill gait speed was slower, but not significantly, in CP (0.86 m/s CP; 0.97 m/s TD). Both groups showed gait related desynchronization. CP had lower mean power and relative power between tasks on the non-dominant side, but neither was significantly different than TD. However, there was a significant difference between the frequency of the peak mu band event-related desynchronization (ERD) with values in both hemispheres slightly but significantly lower in CP. The peak frequency increases rapidly in early development and more slowly until adulthood, so the lower value in CP indicates less cortical maturity or an abnormality.

Conclusions: We anticipate that the subtle differences demonstrated here would be even greater in those with CP who have poorer mobility or hand function (e.g. in GMFCS or MACS level III). Our current research is on treadmill gait in children with bilateral CP in GMFCS Levels II-III and in infants (< 2years) at high risk of CP, and on hand function in children with bilateral CP, MACS Levels II-III. We are increasingly aware that children with CP may

demonstrate individualized patterns of brain activation that are not obvious from assessing motor function alone, and some of which may be more adaptive than others.

1. George KA, Damiano DL, Kim Y, Bulea TC. Mu Rhythm during Standing and Walking Is Altered in Children with Unilateral Cerebral Palsy Compared to Children with Typical Development. Dev Neurorehabil. 2020 May 6:1-10.
2. Short MR, Damiano DL, Kim Y, Bulea TC. Children With Unilateral Cerebral Palsy Utilize More Cortical Resources for Similar Motor Output During Treadmill Gait. Front Hum Neurosci. 2020 Feb 14;14:36.

Assessing Emergent Stepping in Infants with and without Cerebral Palsy via Gait-Locked Electrocortical Activity

Julia Kline (National Institutes of Health)*; Thomas Bulea (National Institutes of Health); Lauren Hirth (NIH); Diane Damiano (National Institutes of Health) *{*klineje@nih.gov*}

Motivation: Electroencephalography (EEG) has been used to study cortical activity during walking in adults (Gwin et al., 2011, Bulea et al., 2015) and during infant motor development (Gonzalez et al., 2016); however, very little is known about cortical activation during the emergence of walking. Better understanding the role of the cortex during walking development may inform earlier diagnostics and therapies for infants and children with cerebral palsy (CP). Infants present unique challenges for EEG data acquisition and analysis compared to adults (Norieka et al., 2020). One specific challenge is recording sufficient gait cycles for analysis, given discontinuous step patterns in novice walkers. It is therefore necessary to develop novel strategies to examine infant stepping EEG data. In this study, we examined EEG cortical activity time-locked to gait events, e.g. right/left foot-offs/foot-strikes, rather than complete gait cycles, in five infants with and without CP, who were not yet able to walk independently, during supported treadmill stepping.

Methodology: These data are part of a larger IRB-approved protocol investigating brain activity in infants and children with and without CP during motor skill development. Data collection is ongoing, but we present data here on three typically-developing (TD) infants (10.0, 10.3, and 14.3 months) and two infants with CP (16.8 and 14.7 months, unilateral and bilateral CP, respectively). The TD infants could sit and pull to stand; additionally, one could crawl, and one could cruise and walk with one hand held. Both infants with CP could sit, pull to stand, crawl, and walk with two hands held, though only one was cruising.

An active, 64-channel EEG system (Brain Products, Morrisville, NC) was time-synchronized with motion capture (Vicon Motion Systems, Denver, CO) during the collection of resting and stepping trials. Resting trials were recorded while participants sat and watched a silent video. During stepping trials, participants walked on an infant treadmill with a physical therapist providing minimal underarm support.

EEG data were processed in MATLAB (Mathworks, Natick, MA) using EEGLABv14 functions (Delorme and Makeig, 2004). EEG data were labeled with gait events derived from the kinematic data, high-pass filtered at 1Hz, concatenated for each participant, re-referenced to a common average, and cleaned by removal of noisy channels and detection/rejection of noisy frames via an artifact subspace reconstruction algorithm (Mullen et al., 2013). Independent component analysis (RUNICA) was applied to parse EEG signals into temporally-independent components (ICs), and each IC was modelled as an equivalent-current dipole. Epochs were extracted from 0.5 sec before to 0.5 sec after left/right foot-strike/foot-off events. Next, a time-frequency decomposition was computed for each IC using the Fast Fourier Transform. Event-related desynchronizations (ERD) and synchronizations (ERS) around the gait events were computed using resting data as baseline. ICs were categorized as gait-related if they showed significant peaks in the mu and/or beta frequencies around selected gait events and decreased spectral power in those bands during stepping compared to rest.

Results: In all five infants, we observed mu and beta ERD in the sensorimotor cortex around foot-strike and foot-off events, relative to rest. For every subject, we identified at least one sensorimotor cortical IC exhibiting gait-locked activity, with equivalent-current dipoles often localized to the premotor and supplementary motor area. The peak mu frequency was lower in these infants than has been observed in older children and adults, as reported previously (Berchicci et al., 2011). We also detected gait-locked spectral power decreases in the anterior cingulate and the posterior parietal cortex in two or more subjects each, which may be related to error monitoring during foot placement and proprioceptive tracking of the limbs in space, respectively. More epochs were retained when individual gait events were considered (mean: 52.2, SD: 31.0) compared to full strides (mean: 7.8, SD: 9.3), making this paradigm more flexible for studying emergent stepping.

Implications: To our knowledge, this is the first EEG study of cortical spectral fluctuations during stepping in infants, paving the way for better understanding of emerging motor skills in normal and abnormal development. We show that infants with TD and CP both exhibit gait-linked spectral fluctuations during this early period of motor skill acquisition. The small sample limited our ability to compare infants with and without CP, however, this remains the ultimate goal of our investigation. Our approach evaluating specific gait events instead of cycles is particularly useful for studying the emergence of walking skills in infants and toddlers, but also has utility in other populations with poor stepping quality or quantity due to motor impairments, fatigue, or other factors.

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Children with bilateral cerebral palsy have poorer motor function but greater cortical activation during a block transfer task

Victoria Hinchberger (National Institutes of Health)*; Diane Damiano (National Institutes of Health); Thomas Bulea (National Institutes of Health); Christopher Stanley (National Institutes of Health); Julia Kline (National Institutes of Health); Si Hyun Kang (National Institutes of Health) *{*tori.hinchberger@nih.gov*}

Introduction: Cerebral palsy (CP) is the most common child-onset motor disability resulting from brain injury early in life. Children with CP experience a range of difficulties when performing functional motor tasks. While EEG has been reported previously in CP, most studies have examined upper limb tasks in children with unilateral CP. We chose here to investigate children with neurological involvement in both hemispheres who are at risk for poorer function in both hands, to provide insights into their patterns of brain activation during a complex upper limb task. Children with bilateral CP were compared to age-related peers with typical development (TD) when transferring paper versus sponge cubes across the midline with both dominant and non-dominant hands while EEG and kinematic data were collected simultaneously. We hypothesized that motor performance would be significantly worse in both hands of children with CP compared to TD, especially when cube types were mixed, and that task differences would be reflected by EEG differences across groups and hands.

Methods: Participants included 14 children with bilateral CP (GMFCS Levels I, II, & III), mean age 13.12 +/ 2.83 years, and 12 with TD, mean age 14.01 +/- 2.46 years. EEG data (64 channels) were collected at 1000 Hz during rest (2 min) and the UE task, which involved grasping a cube on one side of a table and transporting it across the midline to a target on the opposite side. Each performed 3 runs of 15 trials for 3 conditions (paper, sponge, or mixed) with each hand. EEG data were epoched around each transport from grasp to release, based on motion capture data. EEG preprocessing and ICA processing steps (Bulea et al., 2015) were performed using EEGLAB functions (Delorme and Makeig, 2004; Mullen, et al., 2013) After non-cortical components were rejected via manual inspection and the ICLabel plugin, ICs from both groups were clustered on power spectra and dipole coordinates using k-means. A repeated measures general linear mixed model, with group as between and hand and cube types as within subject factors, assessed effects on transfer time, path length, and mu (8-13 Hz) and beta (13-30 Hz) band event-related spectral perturbations (ERSPs), with post-hoc tests as indicated.

Results and Discussion: Motor performance: Significant main effects of group, hand, and condition and hand X group interaction in cube transfer time were found: children with CP were slower than TD ($p < 0.001$), in both hands, and significantly slower in their non-dominant vs. dominant hand ($p = 0.013$). Both groups took longer to

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transport cubes during runs with mixed cubes ($p < 0.001$). Significant effects were also found for path length for group and condition: overall, children with CP took longer paths ($p = 0.016$) and both groups took shorter path lengths with the paper-only condition compared to mixed ($p < 0.001$), potentially due to its lower weight and greater predictability.

Nine clusters were identified with four representing motor and sensorimotor regions based on dipole locations in MNI space (Lancaster, 2000) and global mean ERSPs. In the premotor cluster, a significant interaction ($p=0.035$) between group and condition was found, with post-hoc tests showing greater mu ERD in CP compared to TD in the mixed sponge ($p=0.046$) and mixed paper ($p=0.049$) conditions. These results suggest children with CP may dedicate more cortical resources to movement planning and preparation than TD during the most challenging mixed trial. In beta ERD, there was a significant interaction between group and hand ($p=0.011$); post-hoc tests showed greater beta ERD in CP during nondominant tasks ($p=0.028$) indicating more cortical attention when using the nondominant hand. In the dominant sensorimotor cluster, main effects included greater mu ERD for tasks with the dominant hand ($p=0.015$) and a significant effect of cube type ($p=0.006$) with no significant main or interaction effects in the beta ERD. There were no significant effects on mu or beta ERD in the nondominant sensorimotor cluster, as both groups showed task-related ERD in the sensorimotor areas. In the mid-line posterior parietal cluster, there was a significant effect for hand with greater beta ERD when using the nondominant hand ($p=0.005$).

Conclusion: In summary, children with bilateral CP show preserved sensorimotor ERD but potentially altered activation in the premotor area particularly in the less predictable mixed trial, which was more challenging for them. EEG and motion data revealed differences between groups and within hands in CP, supporting the need for greater focus on upper limb rehabilitation in bilateral CP.

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1:30 – 2:30 • KEYNOTE: Eduardo Macagno & Sergei Gepshtein (UCSD)

Neuroscience and architecture: emerging properties of a new discipline

At the turn of the twenty-first century, a group of architects and scientist in the United States met to discuss the need of collaboration between their disciplines. They were impressed by the emerging evidence of the built environment having pervasive effect our health and well-being. They were equally impressed by the lack of detailed understanding of the causal relationship between specific features of the built environment and the human responses they evoke. Architects and designers use observational data to make design decisions; they examine complex human behavior in complex environments that have many uncontrolled variables. At the same time, rigorous scientific studies have greatly increased our knowledge of human perception and behavior, and their neuronal mechanisms, in such disciplines as behavioral and systems neuroscience, cognitive science and experimental psychology. Can these sciences provide an empirical basis for causal analysis of human interaction with the built environment? What approaches could foster a fruitful collaboration between architects and scientists that will make such analysis possible and develop empirical foundation for design?

Searching for answers to these questions led to the creation of the Academy of Neuroscience for Architecture (ANFA). Launched in 2003 by the American Institute of Architects, the Academy set its goals on promoting "research in neuroscience and cognitive science to improve the design of the built environment." ANFA board of directors is comprised of practicing architects and scientists, with the presidency rotating between representatives of these disciplines. The Academy organizes various meetings and workshops, talks and panels, and it awards seed funding for pilot studies that nurture the establishment of the new discipline.

Today, the ongoing work in this new field of research can be usefully construed as a two-way exchange of ideas, methods and results. Knowledge flowing from science to design helps designers to establish new standards of evidence and rigor in making design decisions. And knowledge flowing from design to science helps scientists to appreciate the cultural and societal implications of their research, and attain a broader perspective on scientific problems that have been defined narrowly and confined to the laboratory. We will consider several examples that illustrate both directions of this cross-disciplinary exchange. We will use sensory and motoric models of perceptual space as a particularly fruitful illustration, and as an arena of imminent and wide-ranging developments in both science and design.

BIOGRAPHIES: Eduardo R. Macagno is a neuroscientist and Distinguished Professor at UC San Diego, where he was recruited as the Founding Dean of the Division of Biological Sciences in 2001. His laboratory investigates neuron circuit formation in the developing nervous system. Another current research project employs biometric devices and Virtual Reality environments to study the interaction of normal and neurologically impaired subjects with the built environment. He was President of the Academy of Neuroscience for Architecture in 2010-12. Macagno has taught courses at UCSD on "Brains and Buildings", and at the New School for Architecture and Design on "Neuroscience for Architecture", with Gil Cooke and Kris Mun.

Dr. Sergei Gepshtein is a scientist at the Salk Institute for Biological Studies in San Diego and an adjunct professor at the University of Southern California in Los Angeles. He works in the areas of perceptual psychology, systems neuroscience and computational neuroscience. His research interests include perception of depth and movement, perceptual organization, planning of multistep actions, and dynamics of cortical neural networks.

At the Salk Institute, he is a member of the Center for the Neurobiology of Vision and the director of Collaboratory for Adaptive Sensory Technologies, which he founded with the goal to translate results of basic science toward applications ranging from architectural and urban design to forensic science. At the University of Southern California, he directs the Center for Spatial Perception & Concrete Experience – a platform for investigating spatial experience as a naturally narrative process. His work has been supported by grants and awards from the National Eye Institute, the National Institute on Aging, the National Science Foundation, the Kavli Institute for Brain and Mind, the Swartz Foundation for Theoretical Neuroscience, and the National Institutes of Natural Sciences of Japan.

He is a founding member of the 5D | World Building Institute, an inaugural member of the Freeman Design Leadership Council (now emeritus), and an inaugural recipient of the Harold Hay Award from the Academy of Neuroscience for Architecture (ANFA). In 2016 he joined the Board of Directors of ANFA to facilitate mutual understanding of science and design professionals and to help build the foundation for a new discipline of design enlightened by results of systematic empirical inquiry.

He has developed an educational curriculum bridging the concepts of space developed by different disciplines in science and design. He has used this curriculum to teach undergraduate and graduate courses at the University of Southern California and at NewSchool for Architecture of Design.

2:30 – 4 • Oral Session: Neuroscience and Architecture

Research in the industry: Brain, building and behavior

upali nanda (HKS; Univ of Michigan) {*unanda@hksinc.com*}

The field of architecture has evolved rapidly in the last few decades. Programs have become more complicated, construction has become more complex, and computation has become integrated into all aspects of design. The years of pen and paper have given way to a new era of parametric design, immersive visualizations, and precise simulations. Building performance has become a foundational concern and focus for many persons. Unfortunately while the nuance and sophistication in designing for the planet has grown, the nuance in designing for people still has many challenges.

In this presentation, Dr. Upali Nanda, the Global Director of Research of a large architectural firm will describe how practice is seeking a better understanding of the relationship between design and human outcomes. She will review the opportunities and challenges of measuring human perception in lived and occupied environments. She will present several case studies where measuring the link between design and human outcomes has been attempted, and where significant methodological challenges still exist. She will present a Live-Learn Lab model of a coalition of practice and academia.

The talk will end with a call for partnerships and an offer to use practice as a living lab for academic research, and vice versa.

Capturing postural dynamics through deep learning

Talmo D Pereira (The Salk Institute for Biological Studies) {*talmo@salk.edu*}

Driven by advances in computer vision and deep learning in recent years, computational ethology has emerged as a field that seeks to develop and apply new methods to study naturalistic behavior in the context of the brain. As these tools developed to study ecologically valid, unconstrained and unstructured behavior, they are highly aligned with the goals of MoBI.

In this talk we will introduce the problem of pose tracking and review tools based on deep learning, developed to solve this problem across a wide range of domains and areas of application. We will demonstrate how markerless motion capture can be used to record biological motion and reveal patterning in the postural dynamics across species, including freely moving flies, mice and humans.

How are architectural affordances reflected in brain dynamics?

Zakaria Djebbara (Aalborg University) {*zadj@create.aau.dk*}

In 1889, Bergson (2001, 2004) suggested that perception is bound by the utility of the body, which he coined virtual action. By virtual action, Bergson referred to perception itself as emerging from all the possible actions upon the object. Almost 80 years later, Gibson's theory of affordances (1966) concurred the same practical view by way of his theory on direct perception. Gibson identified affordances as utility relative to a goal. Their positions share that the body and the perceptual apparatuses are constantly enacted, which consequently locates action in perception. Perception, which is a continuous process, becomes an integration of both sensations, to constitute the stability of the perception, and of an immediate future in the shape of actions—thus, perception is inherently a sensorimotor process. Similarly from an enactivist's view, the preconditions of experience, including experiencing architecture, are rooted in the active processes of sensations and the mobility of the body (Jelić et al., 2016). As the sensorimotor activity involved in perception can be considered intelligently practical, architectural affordances are hypothesized to be reflected in the sensorimotor activity. To investigate this, we used a combination of Virtual Reality (VR) and Mobile Brain/Body Imaging (MoBI) (Makeig et al., 2009; Gramann et al., 2011, 2014), which employs a wearable electroencephalogram (EEG) system, to address architectural affordances. Participants were asked to pass from one space to another in VR through three varying door-widths as transitions. Of the three door-widths, only one condition was unpassable, while the other two ranged from difficult to easily passable. We recorded the brain activity the moment the participants were presented with the respective door width, and of the period of approaching the door. In this experiment, the three possible door-widths illustrate the set of virtual actions, whereas the affordances, i.e. utility relative to a goal, are reflected in the motor-related potentials to succeed in transitioning. Our initial analyses in the time-domain suggested that bad affordances are processed

significantly different from better affordances 50-200 ms subsequent to perceiving the door (Djebbara et al., 2019). In the frequency domain, we hypothesized that while approaching the door, the continuous affordances are expressed as suppression of proprioceptive prediction-errors. As the alpha-band has been linked with predicted spatial attention over sensorimotor areas (Rohenkohl and Nobre, 2011), we thus expected to find event-related desynchronization (ERD) in the alpha-band over sensorimotor areas while approaching the transition. Our results suggest that the rationale behind the cortical response and perceived design follows an affordance-like pattern, i.e. human beings are enacted organisms whose primary concern involves answering, "How can I act", which in turn composes the preconditions of perception, "What do I perceive". In the context of architecture, since perceptual processes were shown to be modulated by affordances, our results suggest that perception of architecture can be conceived as continuous suppression of virtual actions expressed as proprioceptive predictions. Transitions with worst affordances require greater attention, expressed in the alpha-band. Essentially, the interaction with the world is intelligently practical and practically intelligent in the sense that mobility is at the heart of perceptual processes.

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4:30 – 6 • Oral session: Spatial Cognition

Neural dynamics of real-world movement on invisible routes

Martin Seeber (UCLA)*; Matthias Stangl (UCLA); Uros Topalovic (University of California, Los Angeles); Mauricio Vallejo (UCLA); Daniel Batista (UCLA); Sonja Hiller (UCLA); Nanthia Suthana (UCLA) *{*seeber@ucla.edu*}

Latest technological advancement enables studying real-world behaviors in humans [1-4]. In this study, we combine high-density scalp electroencephalography (EEG) with intracranial local field potentials (LFP) to study neural dynamics during real-world movement. Theta oscillations are especially relevant for spatial representations in the human medial temporal lobe (MTL) [5-7]. We investigate whether walking on specific spatial trajectories would result in LFP time courses predicted by particular, e.g. grid-like, spatial representations. To do so, we designed an asymmetric maze that accordingly would result in differentiable theta dynamics for left versus right walks. In addition to actual walking on these different spatial trajectories, we ask participants to remember their previous or imagine the subsequent route while walking on a treadmill. We aim at identifying discriminative features for left and right walks, which we then utilize to compare data from remembered or planned routes. By combining EEG source imaging and intracranial recordings we expect to gain novel possibilities for identifying large-scale networks related to these task-specific MTL dynamics. Investigating the neural dynamics in the human MTL might reveal relevant functional parallels between spatial representations and knowledge formation and therefore could be instrumental for tailoring neurostimulation based therapies in the future.

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Spatial representations in the medial temporal lobe of freely-moving humans

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Fundamental cognitive functions, such as navigating an environment without getting lost, or episodic memory formation, depend on the ability to process spatial information about one's location and environment. Previous work has shown that the brain supports these functions by encoding neural representations of spatial information, via neurons that show spatially-modulated firing properties (e.g., place and grid cells) as well as oscillatory electrophysiological activity, located primarily in medial temporal lobe (MTL) regions. To date, the vast majority of what is known about the brain's spatial representation system stems from research in non-human animals, or humans tested under non-naturalistic conditions (e.g., stationary participants performing tasks on a computer screen) with limited ecological validity. Moreover, previous work in this field has focused on how the brain encodes spatial information about one's self (e.g., one's own location, orientation, and movements), while it remains unclear how other individuals are integrated into our 'cognitive map' of the environment during social experiences. To address these questions, we have developed a technical platform to investigate human brain activity in clinical patients with permanently implanted intracranial electrodes, enabling us to obtain electrophysiological recordings from deep brain structures during naturalistic real-world experiences and ambulatory movement. We found that human MTL oscillations encode several types of spatial representations during real-world navigation, such as information about one's own location, self-motion speed and movement direction. Most strikingly, we discovered that these neural representations encode information not only for one's self, but also serve to keep track of other people's location and movements in shared environments. Together,

these findings provide evidence that the human brain uses common neural mechanisms to encode spatial representations for oneself and other individuals, and shed new light on the neural substrate underlying spatial navigation and awareness of others in real-world scenarios.

Multisensory input improves navigation of patients with hippocampal lesions in a virtual Morris Water Maze

Deetje Iggena+ (Charité Universitätsmedizin Berlin); **Sein Jeung**+ (TU Berlin)*; Patrizia Maier (Charité Universitätsmedizin Berlin); Carsten Finke (Charité Universitätsmedizin Berlin); Klaus Gramann (TU Berlin); Christoph Ploner (Charité Universitätsmedizin Berlin) *{*sein.jeung@campus.tu-berlin.de*}+ authors contributed equally

Spatial navigation is a complex multisensory process that requires the integration of visual, somatosensory and vestibular input and re-afferents from the motor system with mnemonic representations of the environment. Despite this complexity, most human adaptations of the Morris water maze (MWM, Morris et al., 1982) in spatial navigation studies are implemented in stationary desktop-setups that lack the full set of multisensory inputs accompanying real-world navigation. Consequently, these paradigms have limited explanatory power for the processes subserving real-life navigation in humans (Diersch & Wolbers, 2019). Here, we aim to address this issue by exploring the use of a mobile brain-body (MoBI, Makeig et al., 2009; Gramann et al., 2011; 2014) setup in healthy participants and in patients with lesions of the medial temporal lobe including the hippocampus. Hippocampal pathology has frequently been associated with deficits in desktop variants of the MWM (Astur et al., 2002; Feigenbaum & Morris, 2004), indicating the role of the hippocampus as a key structure for navigation across species.

Eleven patients and 22 age- and sex-matched control participants (two per patient) were equipped with a 128-channel high-density EEG system and performed a virtual MWM task in a circular arena surrounded by a wall with clearly visible extra-maze landmarks that allowed for computing an allocentric representation of the goal location. Each experimental block consisted of 7 trials: in the first three trials (learning), participants repeatedly navigated in the arena starting from a fixed location to search for a hidden target, which became visible when approached. In the following four trials, they were asked to navigate back to the remembered location of the target and then press a button (probe). Three out of the four probe trials started from a different location rotated around the center of the arena by 90, 180, or 270 degrees. The target location remained constant within a block but varied between blocks.

For every participant, a set of six blocks was presented in each session. In one session, the six blocks were presented in a stationary (STAT) setup, where the experiment was presented on a flat screen from a first-person view. In another session, the blocks were presented in a mobile (MoBI) setup using HTC-Vive head-mounted virtual reality goggles, allowing participants to move in the physical space. Across the two sessions, the principal spatial layout was maintained, but virtual scenes differed, to avoid memory transfer between the MoBI and STAT conditions. The order of the two sessions was counterbalanced across participants. In all blocks, EEG was recorded continuously. In the MoBI condition, the position and orientation of the feet and torso were tracked.

Overall, significant main effects of setup and group on performance were found, i.e., all participants performed better in the MoBI condition with controls performing better than patients. The interaction between the two factors was statistically nonsignificant. However, the magnitude of improvement in performance in the MoBI condition was larger in patients than in controls. Despite this larger improvement, spatial precision of the performance of patients in the MoBI condition was lower than that of controls in the same condition, implying the role of the hippocampus in encoding spatial information in high precision. A significant interaction between factors setup and participant group was found in mean dynamic time-warped distance between the last learning trial and the four probe trials. The dynamic time-warped distances reflect how closely participants replicated the trajectory from the last learning trial in order to navigate back to the remembered target location in probe trials. The significant interaction indicates that the increase in MTL group's tendency to replicate previously navigated trajectories in MoBI setup was larger than that of control group. On the other hand, the average angular velocity at the beginning of probe trials became selectively larger in control groups in MoBI relative to STAT condition, implying that the ease of rotating the head in MoBI led the controls, but not the MTL group, to look around more at trial onset.

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Put together, the results show that both groups' performance improved in MoBI but through distinct navigation strategies. When navigating in MoBI condition, the MTL group showed more trajectory-replicating behavior, and the control group more head-turning behavior. In line with established findings about hippocampal involvement in allocentric coding of spatial information (Feigenbaum & Morris, 2004), it can be speculated that the impairment in allocentric coding caused by the lesion led the patients to use the additional idiothetic/proprioceptive input in MoBI to refine their egocentric representation of space as opposed to allocentric representation.

These findings show that multisensory input and motor re-afferents significantly contributes to successful navigation in real-world environments. In the EEG analysis to follow, we will examine the signal source-localized to the parietal retrosplenial regions, which are known to be involved in multisensory integration and conversion between the view-dependent egocentric representations of space and the map-like allocentric representation.

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FRIDAY, JUNE 10

9 – 10:30 • Oral session: MoBI in Music/Dance/Arts

The role of the motor system in rhythm perception

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We will briefly introduce the panel on MoBI in Music/Dance/Arts. Further, we will make the point the the methods of MoBI are useful not only in studying the brain and body in motion, but can be important for understanding perception in absence of overt movement. We will illustrate using recent experiments testing our hypothesis that the motor system plays a necessary role in the perception of rhythms by providing a scaffolding for temporal expectations, the Action Simulation for Auditory Perception (ASAP) hypothesis (Patel & Iversen, 2014). In recent work on the perception and imagery of rhythmic hierarchies, MoBI method were used as important controls for overt movement (Cheng, Creel & Iversen, 2022).

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Inter-Brain Synchrony in a Creative Writing Workshop (z)

Akanksha Acharya (University of Houston)*; Jesus G Cruz-Garza (Cornell University); Mauricio A Ramírez-Moreno (Tecnológico de Monterrey); Cristina Rivera Garza (University of Houston); Jose Contreras-Vidal (University of Houston) { akanksha.acharya14@gmail.com}

Background and Significance: The neuroscientific study of the human creative process has dealt mostly with deliberate forms of creativity, by asking participants to engage in a specific creative task in isolation for the particular experiment [1, 2]. Mobile brain-body imaging technology provides a powerful tool for the exploration of on-site creative interactions [3], as the human creative process occurs naturally in social interactions [4]. In the context of creative writing, neuroscientific studies have been conducted as participants imagine, create, and revise a creative text in isolation [5,6], focusing on cognitive processes within the boundaries of individual brains. However, the process of writing is a community experience: from the shared language we use; including ideas, symbols, and metaphors, to the bodily interaction in shared experiences and spaces [7]. An important part of the creative writing process, especially for the training of students, are creative writing workshops where students read, comment, and discuss their peers' text drafts.

Methods: Synchronization of brain activity between two people interacting face to face results primarily from direct social interactions that include multimodal sensory integration, potentially driving temporal alignment between the participants' brain activity. Here, we analyzed temporal synchronization of brain electrical activity between students in response to communication cues in a real-world classroom setting. Students developed creative writing skills, discussed, and commented on their peers' texts while their brain activity was recorded during a 50 minutes long creative writing workshop. EEG data was acquired at 500 Hz using a 32 channel EEG (BrainAmp DC with actiCAP, Brain Products GmbH), following the 10-20 international system. Data of three bilingual students was recorded and further analyzed, as they discussed and evaluated their peers' first draft of a creative text. The session was videotaped and manually annotated to identify communication-relevant 'events': a new comment made by any student or instructor (e.g. comment event: "[…] estar ocupando todo el territorio de la página y decir: 'Hay una experiencia con el espacio que yo tuve en el cementerio que quiero replicar aquí.'"). A bispectral analysis was implemented to quantify the degree of phase coupling [8] of EEG signal between pairs of students. Bispectral values were calculated in five frequency bands (Delta 1-4 Hz, Theta 4-8 Hz, Alpha 8-12 Hz, Beta 12-30 Hz, Gamma 30-50 Hz), before and after an event: 500 ms to 10 ms before the event, and 200 ms to 500 ms after the event.

Results: Our main finding was a statistically significant (Kruskal-Wallis, $p < 0.05$) increase of phase synchrony between pairs of students' EEG data, reflected as higher bispectral values after a new comment was made. This increase was observed for the Delta, Theta, and Gamma bands; while the opposite change was found for the Alpha band. This effect was shown between channel C4, an electrode over the primary motor cortex over the right hemisphere, across all participant dyad combinations as the workshop progressed. This scalp area has been associated with isometric head rotation [9], as well as neural synchronization in C4 due to mutual gaze [10], corresponding with a behavioral response by the participants to follow the comment origin. Also, phase synchronization levels between participants decreased by 25% by the end of the session.

Conclusions: These results might represent important educational implications. First, the introduction of a new question or comment during the classroom communication process acted as trigger for a peak in inter-subject bispectrum. This brings the students' brains in the classroom to mutual alignment state, with higher receptivity during these times in a pair of participants. Sensory information arriving during these high-receptivity periods of neural alignment is more likely to be encoded than in low receptivity periods [10]. Peer interaction sends stronger intentional signals that produce more effective information receptivity alignment, and thereby improving learning outcomes in classroom settings.
This study might contribute in the development of new measurements to incorporate in brain-computer interfaces based on neural synchrony, and in the design of assistive learning intervention systems that could optimize information transfer between students. The tracking of brain-to-brain synchronization during social interaction can improve creative collaboration and overall classroom performance, by providing information on group dynamics and neural features derived from spontaneous communication.

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Brain-Body Music Interfaces for Creativity, Education, and Well-Being

Grace Leslie (Georgia Institute of Technology)* *{*grace.leslie@gatech.edu*}

Music is an important and universal means of communication. The feelings of connection and well-being that music creates are supported by a process in the brain and body called entrainment, in which our natural rhythms (speaking, walking, heartbeats, breathing, and even brain waves) synchronize with the rhythms we hear. The research activities I supervise at the Brain Music Lab at Georgia Tech expand on this powerful process by building software and hardware that translates brain and body rhythms into music and sound. I will review several music technologies that invite beneficial brain and body rhythms within and between listeners, and I will introduce the musical performance and composition practice I've developed in concert with these technologies. For researchers, doctors, and caretakers, this work has the potential to expand our scientific understanding of music's beneficial effects on the brain and body, and may lead to new music-based interventions for adults, children, and infants.

Collective dynamics support group drumming, reduce variability, and stabilize tempo drift

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Motivation. Humans are social animals who engage in a variety of collective activities requiring coordinated action. Among these, music is a defining and ancient aspect of human sociality. Social interaction has largely been studied in dyadic contexts. The presence of multiple agents engaged in the same task space creates different constraints and possibilities that have been studied more extensively in nonhuman animal behaviour.

Methodology. We addressed whether collective dynamics play a role in human circle drumming. The task was to synchronize in a group with an initial reference pattern and then maintain synchronization after it was muted. We varied the number of drummers, from solo to dyad, quartet, and octet.

Results. The observed lower variability, lack of speeding up, smoother individual dynamics, and leader-less inter-personal coordination indicated that stability increased as group size increased, a sort of temporal wisdom of crowds. We propose a hybrid continuous-discrete Kuramoto model for emergent group synchronization with pulse-based coupling that exhibits a mean field positive feedback loop.

Implications. This research has theoretical implications about collective intentionality and social cognition. We also discuss if it this task creates possibilities for addressing the neural substrate of group action.

Implementing interpersonal synchrony biofeedback in real-world social and artistic contexts

Phoebe Chen (NYU)*; Kaia Sargent (UCLA); Sophie Hendrikse (VU Amsterdam); David Medine (Diademics); Matthias Oostrik (Magdatt); Guillaume Dumas (University of Montreal); Suzanne Dikker (NYU)
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Recent years have seen a dramatic increase in studies measuring brain activity, physiological responses, and/or movement data from multiple individuals during social interaction. Such "hyperscanning" research has demonstrated that brain activity may become coupled across people as a function of a range of factors. Findings from this field not only underscore the potential of hyperscanning techniques to capture meaningful aspects of naturalistic interactions, but also raise the possibility that hyperscanning can be leveraged as a tool to help improve such naturalistic interactions. Building on our previous work showing that exposing dyads to real-time inter-brain synchrony neurofeedback may help boost their interpersonal connectedness, we describe the biofeedback application Hybrid Harmony, a Brain-Computer Interface (BCI) that supports the simultaneous recording of multiple neurophysiological data streams and the real-time visualization and sonification of inter-subject synchrony. We report results from 236 dyads experiencing synchrony neurofeedback during naturalistic face-to-face interactions, and show that pairs' social closeness and affective personality traits can be reliably captured with the inter-brain synchrony neurofeedback protocol, which incorporates several different online inter-subject connectivity analyses that can be applied interchangeably. Hybrid Harmony can be used by researchers who wish to study the effects of synchrony biofeedback, and by biofeedback artists and serious game developers who wish to incorporate multiplayer situations into their practice.

FRIDAY, JUNE 10

10:45 – 12:15 • Oral session: MoBI in Arts & Therapy

Panel Overview: Imaging the interface: MoBI and creative arts; research and applications

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Overcoming restrictions of traditional brain imaging technologies with Mobile Brain-Body Imaging (MoBI) allows studying cognition in natural settings and provides an ecologically relevant approach to the connections among the brain, body, and behavior (Gramann et al., 2011, 2014; Ladouce et al., 2017). The use of MoBI to study clinical health populations is apt for expanding and offers more direct investigation of the neurophysiological signals associated with behavior in psychotherapeutic encounters (King & Parada, 2021). The arts, traditional psychotherapy, creative arts therapy, and cognitive neuroscience all contribute and translate knowledge in this emerging field; novel applications of MoBI are illuminating biological dimensions of relational practices and aesthetic productions and providing insights into therapeutic potentials for clinical health populations. This inquiry is naturally aligned with theories of embodied cognition (see for example 4E approach as in Newen et al., 2018; Parada & Rossi, 2020) and uniquely poised to advance transdisciplinary research for clinical health populations (Dikker et al., 2020; Parada & Rossi, 2020). Artistic expression—heavily relying on movement—involves an engagement of visual, perceptual, sensory, cognitive, and emotional systems (King & Parada, 2021) and contemporary studies are illuminating the capacities for MoBI to investigate real-time changes in brain dynamics and behavior during the process of learning and performing (Barnstaple et al., 2020). Embodied and situated theories of cognition have gained increased attention in recent times. Conceptualizing cognition as socio-culturally embedded, intersubjective, and participatory action-based practices and capabilities has been furthered by recent data using MoBI. This perspective complements a growing awareness around the importance of sociocultural practices in supporting health and changing the course of disease (Bearss & DeSouza, 2021). Systematically integrating theory and data will drive collaborative discussion for how nuanced concepts of embodiment, synchrony and interoception can be measured using MoBI.

This panel will discuss transdisciplinary theory and research strategies at the interface of the creative arts therapies and neuroscience, and specifically investigate how MoBI capacities can enhance cultural and scientific understanding of the unique role of arts in health and well-being. Panel members will provide a brief historical context and overview of what has been accomplished at the intersection of creative arts therapies and contemporary neuroimaging, along with relevant studies that utilize physiological and biological tracking to understand the mechanisms by which the arts influence cognitive, emotional, and embodied brain states. Empirical evidence from recent work in social neuroscience, hyperscanning, dance, and EEG + EKG studies will be presented. With a focus on the reciprocal relationship between research and practical applications, this panel offers a blueprint for a broader research agenda to advance the utility of MoBI at the intersection of neuroscience, arts, and related therapeutics.

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Using MoBI to Advance Research in Neuroscience, Arts, & Related Therapeutics

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Art is everywhere, and a critical part of what it means to be human. The profession of art therapy translates and systematically applies the healing qualities of the arts to mental healthcare within the context of the therapeutic relationship. An understanding of the mechanisms by which art therapy exerts its effects has advanced and the profession is beginning to more accurately identify the underlying factors associated with emotion, cognition and learning that enhance the capacities to change through psychotherapy (Czamanski-Cohen & Weihs, 2016; DeWitte et al., 2021; King et al., 2019; Walker et al., 2018). Central to this inquiry is artistic expression, which involves the engagement of visual, cognitive, emotional, motor, perceptual and sensory systems. (King et al., 2019; Lusebrink & Hinz, 2020; Tinio, 2013; Vaisvaser, 2021). Despite the growing evidence that attests to the success of art therapy interventions, and the inclusion of relevant neuroscientific findings that serve to explore and define its theory and practice, the biological mechanisms that explain the value of art therapy are nascent and not yet known (King & Parada, 2021). Firming the neurobiological basis for art therapy theory, research and practice will bolster awareness and support for the profession, and increase efficient, systematic and comprehensive evidence-based care.

Neuroaesthetics is an emerging subdiscipline of cognitive neuroscience investigating biological mechanisms involved in making and viewing art (Chatterjee & Vartanian, 2014; Skov & Vartanian, 2009). Typically these studies take place in the lab and elicit data that could be meaningful but is not typically or directly translatable to the therapeutic context. Understanding the cognitive and emotional components of aesthetic productions can be enhanced and grounded through the concreteness afforded through (neuro)physiological measures accompanied by behavioral observations and subjective associations from the art therapist (King & Parada, 2021). Overcoming restrictions of traditional brain imaging technologies with Mobile Brain-Body Imaging (MoBI) allows studying cognition in natural settings and provides an ecologically relevant approach to the connections among the brain, body, and behavior (Gramann et al., 2011, 2014; Ladouce et al., 2017).

Transdisciplinary collaboration is the future of knowledge making in advanced post-industrial societies and there is a growing awareness that the most vexing problems we face cannot be solved by any single discipline (King, 2018). This presentation will present clinically relevant examples for how art therapy, neuroaesthetics and MoBI can be used to understand, explore, and advance therapeutic potentials for clinical health populations such as Parkinson's disease and psychological trauma.

Moving Targets: Embodiment and attention in a dance based MoBI paradigm

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Neuroscience of dance is an emerging field with important applications related to health and wellbeing. Dance has shown potential to foster adaptive neuroplasticity (Rehfeld et al., 2018) and slow the progression of neurodegeneration in diseases such as Parkinson's (DeSouza & Bearss, 2018) and Alzheimer's; however, the multimodal nature of dance presents challenges to researchers aiming to identify mechanisms. Dancing requires simultaneous engagement of motor and cognitive domains, involving visuomotor transformations, timing, memory, and spatial awareness. Studies to this point have assessed the impact of dance on brain dynamics and structure through pre/post tests (Muller et al 2017, Burzynska et al., 2017) or studies on expertise (Karpati et al., 2015; Burzynska et al., 2017), as traditional brain imaging modalities restrict participant movement to avoid movement-related artifacts. Here, we used Mobile Brain/body Imaging Mobile Brain/body Imaging (MoBI; Makeig et al., 2009; Gramann et al., 2011; 2014) to investigate real-time changes in brain dynamics and behaviour during the process of learning and performing a novel dance choreography. This builds on studies from our group that have shown dance-based learning over 8-months produces BOLD signal changes in SMA using fMRI (Bar & DeSouza, 2016) and resting state alpha power increases in frontal cortex post-dance in people with Parkinson's disease compared to controls (Levkov et al., 2014).

Our current project assessed the impact of dance on brain dynamics and motor learning while subjects (n=16) engaged with a novel 30-second choreography. Trials included watching VIDEO (4 times), watching LIVE performances of the choreography (6 times), moving with the teacher (LEARN; 3 to 20 times), imagining performing from a first-person perspective (IMAGINE; 6 times), and finally performing in space (PERFORM; 6 times). Sessions were recorded at the Berlin Mobile Brain/Body Imaging lab (BeMoBIL) which allows for acquisition of motion capture data synced with continuous recording of wireless mobile EEG (Brain Products ActiCap; 128 electrodes) in a dedicated 150 m2 lab space. Movements were recorded using 10 HTC Vive trackers running on Steam VR and music was rated for valence pre/post learning.

The results demonstrate that all participants reached our target criteria of 80% or higher accuracy in reproducing the movement sequence within 20 LEARN trials; however, previous dance training was associated with significantly fewer LEARN trials required to reach criteria (T-test, $P<0.0001$). This suggests that experience may be associated with differences in learning or attention, an important distinction as therapeutic applications of dance often involve non-expert populations who could benefit from enhanced understanding of these processes. "Embodiment" and "expressivity in movement" were recently identified as therapeutic factors specific to dance/movement therapy (deWitte et al., 2021), pertinent to our subjects' reports of an enhanced "sense of dancing" over trials. Next steps include frequency analysis of EEG data along with movement analysis, to identify properties of motion data and brain-based signals associated with shifts in embodiment and attention pre/post and during dance-based learning.

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Harmonic Dissonance: interpersonal neurofeedback as a tool to foster art/science dialogue

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There is growing interest in art-science initiatives. Institutes, workshops, artist-in-residences are popping up everywhere. These collaborations come in different shapes and forms, and are often asymmetric, with a focus on artists becoming part of (natural) scientific experimentation. For example, some scientists have argued that working with artists can assist in science communication (Zaelzer, 2020) or in meeting therapeutic goals (King, 2016). We describe a longstanding collaboration where artists and scientists are equal partners in the co-creation of audience experiences that serve scientific and artistic goals, together and independently. Researchers, dancers,

interactive media artists, and sound designers together explore to what extent "objective" records of (bio-)physical phenomena (brainwaves, heart rate, movements) can tell us something about the "subjective" experience of how connected we feel to each other. We challenge the duality between subjectivity and objectivity that is often associated with art and science and find that "synchrony" can serve as a boundary object for interdisciplinary discussion (Halpern, 2012): we leverage terminological frictions as a fertile space for creative imagination and artistic, scientific, and therapeutic in(ter)vention (Ayrolles et al., 2020; Chen et al., 2021).

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MoBI meets MoBE: Towards translational neuroscience in the real world

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Evidence shows the fact that replicability of cognitive processes and brain activity findings is highly improved when conducting studies with high statistical power that adhere to well-defined and standardized analysis pipelines. Thus, recent initiatives such as the Open Science Collaboration, #EEGManyLabs, and others will greatly improve psychological and brain sciences in the near future. Nevertheless, such effort is not straightforward or easily translatable for the MoBI/4E research program. Here I present a collaborative solution based on the construction of the first neurobehavioral biobank, which integrates Mobile Brain/Body Imaging (MoBI) and the Microbiome of the Built Environment (MoBE) with bioinformatics, the arts, as well as open and citizen science. Thus, the international repository of multi-site neurobehavioral biobanks will become an important tool for the MoBI/4E research program contributing robust evidence towards personalized medicine by supporting scientific progress in stratification of population as well as biomarker discovery and validation.

FRIDAY, JUNE 10

1:30 – 2:30 • KEYNOTE: Helen Huang (University of Central Florida)

"Ground truth" motion artifacts and the influence of hair on EEG recordings

Motion artifacts and hair have posed challenges for recording high-fidelity EEG signals since the technique was first used and continue to be a problem. One recent innovation to address motion artifacts is the development of dual-layer EEG. One side of a dual-sided EEG electrode interfaces with the scalp like normal while the other side of the electrode interfaces with a conductive fabric cap to capture the external noise and movement artifacts. An assumption of dual-sided EEG is that the noise signal is the "ground truth" motion artifact, which is also present in the signal recorded from the scalp. In my lab, we are testing this assumption of dual-sided EEG electrodes using bench top tests. To date, we have found that the signals recorded from each side of a dual-sided EEG electrode with mirrored interfaces do not necessarily share the same temporal or frequency characteristics. Regarding the influence of hair on EEG research, recent discussions related to systemic racism in neuroscience have raised concerns that EEG research may not represent all racial and ethnic communities due to differences in hair characteristics. Voluminous, curly, and tightly coiled hair features, which are most found on individuals in the Black community, can pose difficulties with preparing and recording EEG. I will share results from a research survey of the EEG community addressing this topic (https://hellobrainlab.com/research/eeg-hair-project/). Current results suggest that there is indeed a disproportionate exclusion of Black folks in EEG research. For mobile brain/body imaging findings to have the desired impact on science, engineering, medicine, and society, it is critical to consider factors such as different hair types that may inadvertently exclude racial and ethnic communities of the global population.

BIOGRAPHY: **Dr. Helen J. Huang** is an assistant professor in the Mechanical and Aerospace Engineering Department and Biomedical Engineering Program at the University of Central Florida (UCF). She is also a member of the Bionic Materials, Implants, and Interfaces (Biionix) Cluster and the Disability, Aging, and Technology (DAT) Cluster. She directs the UCF Biomechanics, Rehabilitation, and Interdisciplinary Neuroscience (BRaIN) Lab, where her team studies the brain dynamics and neuromechanics of human locomotion and locomotor adaptation. Her team also explores and develops new methods to expand electroencephalography (EEG) capabilities to study human movement. Dr. Huang's research is funded by an NIH R01 and NSF CAREER Award. Her long-term goal is to develop gait and lower limb rehabilitation approaches based on brain dynamics and multimodal neuromechanics. She earned her PhD in biomedical engineering from the University of Michigan and completed a postdoctoral fellowship at the University of Colorado Boulder.

FRIDAY, JUNE 10

2:30 – 3:30 • Brain Products MoBI Award

3:30 – 4:00 • Closing Ceremony

4:30 – 6 • MoBI Moonshot

To end the conference, a panel and audience discussion where we can collectively take stock of where we are and share our visions for where we are going. A range of perspectives are represented on the panel and we invite everyone to ponder these topics and weigh in during open discussion

Topics:

1) Where is the field now?

e.g. what are some of the major landmarks, accomplishments and/or milestones you've observed?

2) Where are we going?

e.g. Where can we expect to be in 5 years? 10 years? 25 years?

What is your vision or dream for the future of MoBI as a field and a community?

What are the major opportunities you see ahead?

3) How will we get there?

e.g. What are some of the technical/analytical hurdles that need to be solved?

What new equipment/analysis methods do we need?

What are some untapped collaborative opportunities?

What funding opportunities do you see as promising?

4) Moonshot Visions

What would be a dream project(s) be to move the field forward, if resources were no object?