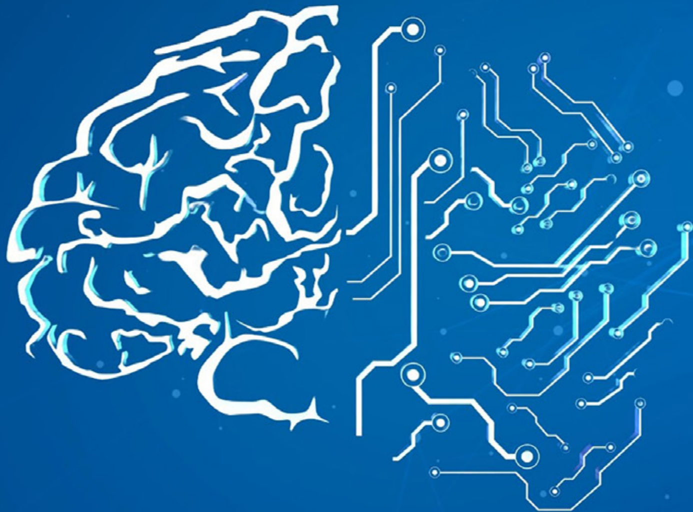

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MoBI CONFERENCE – 5th International Mobile Brain/Body Imaging Conference
Book of Abstracts

Editors: Manca Peskar, Uros Marusic, Klaus Gramann, Sein Jeung

Editor-in-Chief of the Publishing House: Tilen Glavina
Editor for Life Sciences: Boštjan Šimunič
Technical editor: Alenka Obid
Design and Typesetting: Alenka Obid
Publisher: Znanstveno-raziskovalno središče Koper, Slovenija/Science and Research Centre Koper, Slovenia
Publisher represented by: Rado Pišot
Adress: Garibaldijeva 1, 6000 Koper, Slovenia
Online publication
Available at: https://doi.org/10.35469/978-961-7195-56-9
DOI: https://doi.org/10.35469/978-961-7195-56-9
Koper, 2024

Kataložni zapis o publikaciji (CIP) pripravili v Narodni in univerzitetni knjižnici v Ljubljani
COBISS.SI-ID 215125763
ISBN 978-961-7195-56-9 (PDF)

MoBI 2024

5th International Mobile Brain/Body Imaging Conference

June 2–5, 2024,
Piran, Slovenia

The Mobile Brain/Body Imaging (MoBI) Conference brings together researchers from technical and natural sciences and the humanities. The conference fosters scientific communication, networking, and good scientific practices related to MoBI research. By combining mobile brain imaging methods like EEG and fNIRS with motion capture and other data streams, MoBI facilitates the investigation of brain activity during active movement and interaction with the environment. MoBI experiments elucidate the human brain function of actively behaving participants in their embodied and naturalistic states.
The 5th International Mobi conference was hosted by the Science and Research Centre Koper and took place between June 2-5, 2024, in Piran, a charming city in the Istria region with beautiful beaches and architecture. All submitted abstracts were peer-reviewed by members of the scientific committee.

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Klaus Gramann, Professor, PhD Chair Biological Psychology & Neuroergonomics, Berlin Mobile Brain/Body Imaging Lab (BeMoBIL), TU Berlin

Uroš Marušič, Associate professor, PhD, Senior Research Associate
Science and Research Centre Koper, Institute for Kinesiology Research

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Intelligent Biomedical Sensing (IBS) Lab, Berlin Institute for the Foundation of Learning and Data, TU Berlin

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Department of Psychology, Neuropsychology Lab, University of Oldenburg

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Department of Biomedical Engineering, Human Neuromechanics Laboratory, University of Florida

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Ergonomics, IfADo – Leibniz Research Centre for Working Environment and Human Factors at TU Dortmund

Local Organizing Team

Manca Peskar, PhD student
Science and Research Centre Koper, Institute for Kinesiology Research; Biological Psychology and Neuroergonomics, Berlin Mobile Brain/Body Imaging Lab (BeMoBIL), TU Berlin

Tisa Hodnik
Student Assistant | Volunteer
Science and Research Centre Koper, Institute for Kinesiology Research

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KielMotionAnalysisToolbox (KielMAT): A Python Toolbox for Motion Data Processing in Neuroscience and Biomechanics

Abedinifar, Masoud; Hansen, Clint; Maetzler, Walter; Romijnders, Robbin; Welzel, Julius

Kiel University, Germany

The KielMotionAnalysisToolbox (KielMAT) is a Python-based, open-source toolbox currently under development aimed at a range of motion data processing pipelines in neuroscience and biomechanics.
This presentation aims to showcase the current developmental status of KielMAT, featuring examples of gait data processing using validated algorithms. The initial segment will introduce the toolbox's design concept, emphasizing its core data classes aligning with Motion-BIDS principles. The design should provide compatibility and optional integration with other BIDS formats. The second part will consist of examples on how the currently implemented algorithms for Gait Sequence Detection (GSD), Initial Contact Detection (ICD), and Physical activity monitoring (PAM) perform against gold standards on clinical cohorts.
We believe that this toolbox, streamlining existing solution, can cater the growing need for open-source solutions in motion research. It offers (Motion-)BIDS compatibility to facilitate data exchange and collaboration. Currently KielMAT is under review at JOSS (https://github.com/openjournals/joss-reviews/issues/6842) and will hopefully provide a valuable resource for processing motion data in both neuroscience and biomechanics research in the future.

Key words: Biomechanics, Gait, BIDS, Toolbox

Passive and active Lokomat-assisted Gait modulates Cortico-muscular connectivity

Artoni, Fiorenzo [1]; Cometa, Andrea [2]; Dalise, Stefania [4]; Azzollini, Valentina [3]; Micera, Silvestro [5]; Chisari, Carmelo [4]

1: University of Geneva, Geneva, Switzerland;
2: Scuola Superiore Sant'Anna, Pisa, Italy;
3: University of Pisa, Pisa, Italy;
4: Pisa University Hospital, Pisa, Italy;
5: EPFL, Geneva, Switzerland

The effects of robotic-assisted gait (RAG) training, besides conventional therapy, on neuroplasticity mechanisms and cortical integration in locomotion are still uncertain. To advance our knowledge on the matter, we determined the involvement of motor cortical areas in the control of muscle activity in healthy subjects, during RAG with Lokomat, both with maximal guidance force (100 GF—passive RAG) and without guidance force (0 GF—active RAG) as customary in rehabilitation treatments. We applied a novel cortico-muscular connectivity estimation procedure, based on Partial Directed Coherence, to jointly study source localized EEG and EMG activity during rest (standing) and active/passive RAG. We found greater cortico-cortical connectivity, with higher path length and tendency toward segregation during rest than in both RAG conditions, for all frequency bands except for delta. We also found higher cortico-muscular connectivity in distal muscles during swing (0 GF), and stance (100 GF), highlighting the importance of direct supraspinal control to maintain balance, even when gait is supported by a robotic exoskeleton. Source-localized connectivity shows that this control is driven mainly by the parietal and frontal lobes. The involvement of many cortical areas also in passive RAG (100 GF) justifies the use of the 100 GF RAG training for neurorehabilitation, with the aim of enhancing cortical-muscle connections and driving neural plasticity in neurological patients.

Key words: Robotic assisted gait, Rehabilitation, Cortico-muscular connectivity, EEG, EMG

Examining independent components from EEG to study visuomotor response to stimuli in children with and without bilateral cerebral palsy

Bulea, Thomas C.; Kline, Julia; Damiano, Diane L.

Rehabilitation Medicine Department, National Institutes of Health Clinical Center, United States of America

Children with cerebral palsy (CP) have difficulty reaching and grasping due to sensory and motor execution deficits. We examined cortical activity underlying visuomotor integration using a button light up task wherein one of three buttons illuminated at random intervals and participants were instructed to press that button as quickly as possible. 12 children with bilateral CP (13.6±3.0 years; MACS I-III) and 15 typically developing (TD) peers (13.8±2.7 years) completed 60 trials per hand while 64-channel EEG and motion capture were recorded. EEG data were processed using published procedures including independent component (IC) analysis. For each cortical IC, identified using ICLabel, epochs time-locked to button light (visual) and movement (move) onset were generated. Each IC was categorized as attending to visual stimuli, move stimuli, both, or neither using two criteria: a significant ERP peak and significant inter-trial coherence (ITC) within a 400ms window after the relative time-locking event. TD participants had 13 cortical ICs on average versus 14 in CP. Reaction time was significantly ($p=0.019$) longer in CP (430 ms) than TD (374 ms) but was not correlated with the number of ICs. There was no difference in the percentage of ICs responsive to the move cue (CP:16.0%; TD:15.7%) but significantly fewer responded to only the visual cue in CP (4.4%) than TD (10.5%). More ICs responded to both cues in CP (40.3%) than TD (35.6%). These results show that EEG can identify cortical processes underlying visuomotor tasks and suggest less selectivity in brain regions that underly these processes in CP.

Key words: cerebral palsy, ICA, inter-trial coherence, ERP, reaching

Walking modulates visual and auditory perception according to stride-cycle phase

Davidson, Matt; Clouston, Gabriel; Verstraten, Frans; Alais, David

University of Sydney, Australia

We are inherently active beings yet most knowledge about perception stems from seated laboratory experiments that restrict natural movement. This precludes an account of how perception operates in active conditions that are closer to those for which the brain has evolved. Walking is one such frequent and natural voluntary action, yet the consequences of locomotion on perception remain largely unknown.
We developed a new method that uses wireless virtual reality, 3D position tracking of walking participants and continuous probing of perception to obtain a fine sample of perceptual performance within the stride-cycle. Various tasks are completed while participants walk a smooth linear path at a comfortable speed, and investigated for dynamic changes in performance. Our method has revealed new insights, showing that walking elicits oscillations in visual detection performance linked to the rhythm of the step-cycle. Here, we extend this work to other visual and crossmodal tasks. In visual experiments, we observe sinusoidal oscillations in sensitivity and criterion in a two-alternative forced-choice discrimination task, as well as oscillations in the perception of numerosity. In a second series, we observe modulations of audio-visual synchrony and auditory detection performance which are also entrained to the rhythm of the step-cycle.
Together, these results demonstrate that oscillations in performance while walking generalise to a range of visual and crossmodal tasks, advancing our understanding of the links between perception and dynamic action.

Key words: Gait-cycle, stride-cycle, visual perception, auditory perception, virtual reality

Architecture in Mind and Motion: Turning attention in naturalistic paradigms

Djebbara, Zakaria [1,2]; Koselevs, Aleksandrs [2]; Chen, Yiru [2]; Gramann, Klaus [2]

1: Department of Architecture, Design, Media and Technology, Aalborg Universitet, Denmark;
2: Biological Psychology and Neuroergonomics, Technical University Berlin, Germany

As we move, built environments subtly influence our behavior through our sensorimotor system. Unlike seated experiments, the Mobile Brain/Body Imaging technique enables the unfolding of the dynamic complexity of the embodied brain in natural settings. We used a combination of Virtual Reality and mobile electroencephalography to investigate how turning a corner affects the brain and orienting attention. Besides sharp corners affording a higher demand for sensorimotor processing, which we hypothesized to affect attentional resources, we also hypothesized that turning direction acts as an embodied cue traditionally in favor of ipsilateral stimuli. Thus, participants walked down a bent corridor (90°,45°,20°) while spheres appeared (ipsilateral, contralateral) during the walk. Using two controllers, participants pressed the button corresponding to the location of the spheres. Our results reveal significantly decreasing hit rates and increasing reaction times for sharper corners. Surprisingly, ipsilateral stimuli result in significantly slower reaction times and lower hit rates compared to contralateral stimuli. In the neural frequency domain, there is notably increased theta and alpha power over sensorimotor areas during the 90° turn compared to 45° and 20° turns. However, the ipsilateral condition shows significantly lower theta and alpha deviations from baseline over the sensorimotor cortex. These results indicate that the heightened sensorimotor load of sharp corners requires higher attentional resources. Our naturalistic paradigm provides an alternative perspective on attentional resources during movement, highlighting the impact of the built environment on cognitive skills through sensorimotor dynamics. This calls for more naturalistic paradigms as they yield different results compared to seated experiments.

Key words: Architectural Cognition; Neuroarchitecture; Neurourbanism; Naturalistic Paradigms

Evermoving eyes - curse or blessing for mobile EEG?

Ehinger, Benedikt V.

University of Stuttgart, Germany

We ought to understand the brain in the natural environment — a direct motivation for mobile EEG. Natural behavior comprises eye-movements, which are the most common movement of the body, and result in vast change of visual input. Nevertheless, most mobile-EEG tasks are invariant to eye-movements (for now).

No wonder, for decades they were seen more like a curse: introducing muscle-artifacts and forcing us into quasi-experimental settings. Thus, they were “eliminated” by enforcing fixation.

But in mobile EEG they are inevitable, and thus we need to know conceptually: Can we ignore them? Can we control them? Can we address them?

I, personally, think they are, next to locomotion, the most important movement to consider for naturalistic behavior, and I go further (following many others) to argue they are actually a blessing: eye-movements are a natural event marker to understand cognition. They segment our information uptake, and practically spoken, segment our data.

Here, I want to provide an outlook over curses and blessings of using fixation-related potentials in mobile EEG. I will further present some of the solutions we are developing within the regression-ERP framework (using the Unfold.jl toolbox).

I will further try to explore the conceptual space of allowing motion in EEG in the first place (self-motion, eye-motion, object-motion, and their combination), and what pieces might be missing.

If our project proceeds according to plan, I will also present some preliminary data comparing mobile fixation-ERPs with stationary ones.

Key words: regression ERPs, eye-movements, motion

Augmenting Movements using Stimulation: A Research Platform to Investigate Volition in Natural Behavior

Gehrke, Lukas; Gramann, Klaus

TU Berlin, Germany

Experimental MoBI research investigates behavior under natural circumstances. In contrast to stationary experiments, this refers to active behavior at larger spatial scales and with fewer movement constraints. Often, participants act at their own volition: They decide on and take a particular course of action. This key component of natural behavior, has yet to be systematically explored at the scale of MoBI research. Today, emerging wearable stimulation technologies allow to alter participants movements at various thresholds: from noticeable to unnoticeable. With the brain and movement sensing hardware powering MoBI research, these technologies form a research platform to study volition in natural behavior.
We present an interactive prototype based on this platform. We built a brain-computer interface (BCI) based augmentation using electrical muscle stimulation (EMS) to pre-empt participants movements. By classifying readiness potentials from the user's electroencephalogram (EEG), our system controls the user's volitional movements at the time of their intent to interact. In a user study, the system was able to discriminate pre-movement from idle EEG segments with an F1 score of 0.7. We investigated whether such a physical motor augmentation can maintain a user's sense of agency (SoA) as it aligns with the user's predictions: intentional binding, a compression of time between action and outcome, occurred in line with a higher level of control when participants worked with the system instead of being passively moved. This indicates that the system maintained SoA. The prototype leveraged the users' bodies yet still felt natural as it aligned with the users' intentions.

Key words: BCI, EEG, Agency, Volition, Stimulation

From Lab to Life - A Comparative Study on Mobility, Virtual Reality, and Multimodal Integration

Gherman, Diana-Eliza; Fărăgău, Maria; Klug, Marius; Krol, Laurens R.; Zander, Thorsten O.

Brandenburg University of Technology Cottbus-Senftenberg and Zander Labs GmbH, Germany

Passive brain-computer interfaces (pBCIs) have proven effective in implicitly decoding mental states from electroencephalography (EEG), without the need for user's effort. This seamless characteristic could upgrade the way we communicate with machines to more natural human-computer interaction (HCI). However, it is not clear if pBCIs could perform as well in mobile settings pertinent to real life. The mobility aspect is also relevant in the context of Virtual Reality (VR), as its use is prone to dynamic movements. While good accuracies are obtained in controlled laboratories under sitting, desktop-based conditions where the sensitivity of EEG to noise can be managed, practical uses of pBCI might not offer such advantages. This is underscored by studies that found signal alterations when different postures are assumed. It is therefore crucial to investigate if cognitive classifiers' robustness is maintained across other contexts and if psychophysiological measures easier to integrate into daily life could benefit the classification. We aimed to compare the capabilities of a workload classifier across contexts involving varieties in postures (sitting vs. standing), presentation modalities (computer screen vs. VR), and sensors (EEG vs. multimodal). Our findings suggest the pBCI performance is not significantly influenced by the standing posture or the addition of a head-mounted VR (HDM-VR) display to the EEG cap. Moreover, a multimodal pBCI combining EEG, heart rate, and pupillometry data does not perform better than an EEG-based pBCI. Our results give hope for the transition of this technology to real-life applications and offer confidence for the reliance solely on brain signals.

Key words: passive BCI, multimodal BCI, virtual reality

Mobile brain imaging during higher order cognitive processes – on enhanced creativity during walking

Haendel, Barbara [1]; Chen, Xinyu [1]; Murali, Supriya [2]

1: University Hospital Würzburg, Germany;
2: Department of Psychology (III), Julius Maximilians Universität Würzburg

Walking, particularly unrestricted walking, is known to positively affect creativity, such as divergent thinking. Walking is further known to reduce occipital alpha activity and modulate eye-related movements. In a first experiment, we compared the performance in Guilford's alternate uses task (AUT) during walking vs. sitting. Albeit blink rates differed significantly between movement conditions (walking>sitting) and task phase (baseline<thinking<responding), they did not correlate with task performance (walking>sitting). In a second experiment, we explicitly modulated the factor restriction and participants either walked freely or in a restricted path, or sat freely or fixated on a screen. The results showed a movement state-independent effect of restriction on divergent thinking. In other words, like unrestrained walking, unrestrained sitting also improves divergent thinking. Adding mobile EEG, we then tested if occipital alpha power is affected by movement restriction and a possible neural marker for creativity. We confirmed that alpha power was lower during walking, but also found it to be reduced by movement restriction independent of walking or sitting. Alpha power further showed a negative relationship with creativity scores despite the task being purely based on auditory information. Importantly, we discuss a mechanistic explanation of the effect of movement and restriction on divergent thinking based on the increased size of the focus of attention. In recent work, we could corroborate this attentional shift towards the periphery for sensory processing in the visual and auditory domain. Overall, our work shows that movement and movement restriction leads to a general change in state which affects cognitive processes.

Key words: Alpha power, occipital activity, creativity, free walking, mobile EEG

Effect Of Aging and Tai Chi on Gamma-range Lower Limb Corticomuscular Coherence

Hernandez, Manuel Enrique [(1)]; **Hu, Yang** [(2)]

1: University of Illinois Urbana-Champaign, United States of America;
2: San Jose State University, United States of America

Falls in older adults are a prevalent and significant problem. Tai Chi practice (TCP) has been widely used as an evidence-based approach to improve balance and help prevent falls in older adults. However, the neural mechanisms underlying the benefits of TCP are difficult to evaluate during traditional balance assessments due to limitations in typical postural control measures. We evaluate the effects of TCP and healthy aging on cortical and neuromuscular function while standing in realistic and challenging environments. Through the acquisition of electroencephalography and electromyography signals, we examined gamma corticomuscular coherence (CMC) changes in frontal, central, parietal, and occipital cortical areas and lower limb musculature in older adults (n=10), older adults with Tai Chi practice (n=10), and young adults (n=10) under novel virtual reality balance challenging environments. The results showed that older adults have higher gamma CMC in comparison to TCP and young adults as evaluated by the magnitude square coherence. Increased gamma CMC correlated with decreased mediolateral postural sway in older adults, while young adults demonstrated the opposite relationship. Results demonstrate the effects of aging and TCP on CMC during standing postural control tasks, and a potential measure to quantify cortical and muscular adaptation after rehabilitation.

Key words: EEG, aging, postural control, Tai Chi, corticomuscular coherence

EEG dynamics associated with spatial navigation using full-body motion in patients with hippocampal lesions

Jeung, Sein [1,2,3]; Iggena, Deetje [4,5]; Maier, Patrizia [4,5]; Hosgoren, Berrak [6]; Finke, Carsten [4,5]; Ploner, Christoph [4]; Gramann, Klaus [1,7]

1: Technical University of Berlin, Germany;
2: Kavli Institute for systems neuroscience,NTNU, Norway;
3: Max-Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany;
4: Charite Medical University Berlin, Germany;
5: Humboldt University Berlin, Germany;
6: University of Padua, Italy;
7: University of California, San Diego, USA

We implemented human scale virtual Morris Water Maze in desktop and mobile VR and analysed the EEG dynamics in individuals with right medial temporal lesions. Behaviourally, the lesioned group showed better spatial memory when they had access to multisensory input from physical movement.
We computed powers of frontal-midline (FM) and parietal-midline (PM) theta, alpha, beta, and gamma oscillations. The 3-second-long epochs were extracted from temporal sections after trial onset (START), midde portion of a trial (MID), and before submission of learned object location marking the end of a trial (END). After preprocessing, task-related power values were divided by power values during baseline walking trials which did not differ between the groups.
In the desktop setup, FM-theta power in MID section was higher in patients ($p < .01$) and was negatively linked with memory score ($p < .05$, $Rsq = .43$, $F(1,7) = 6.3$). In the mobile setup, controls showed higher FM-theta in START ($p < .01$) and END ($p < .05$) of the trial. FM-theta in START condition was positively related with their memory score ($p < .01$, $Rsq = .40$, $F(1,15) = 10.1$).
This corroborates our interpretation of the behavioural findings that patients' strategy relies on continuous integration of body-based information and its absence in desktop VR leads to exertion of greater cognitive effort in the group. On the other hand, positive relationship between FM-theta and performance in controls implies that their performance in mobile VR depends on landmark-based planning at the beginning of a trial.

Key words: VR, hippocampus, navigation

Low-Dimensional Representations of Visuomotor Coordination in VR

Keshava, Ashima [1]; Wächter, Maximillian A. [1]; Boße, Franca [1]; Schüler, Thomas [2]; König, Peter [1,3]

1: Institute of Cognitive Science, Germany;
2: Halocline GmbH & Co. KG, Germany;
3: University Medical Center, Hamburg-Eppendorf, Germany

Understanding how the eyes, head, and hands coordinate in naturalistic spatial contexts is a key challenge in visuomotor coordination research, often limited by sedentary tasks in constrained settings. To address this gap, we conducted experiments where participants performed pick-and-place tasks on a life-size shelf in a virtual environment, recording concurrent gaze and body movements.
Subjects exhibited intricate translation and rotation movements of the eyes, head, and hands during the task. Employing time-wise principal component analysis on the different streams of 3D data, we reduced the overall dimensionality into 2D representations, capturing over 60% of the explained variance and up to 80% during joint coordination for actions.
Our analysis revealed a synergistic coupling of the eye, head, and hand movements. While generally loosely coupled, they tightly synchronized at the moment of action, with variations in coupling observed in horizontal and vertical planes, indicating distinct mechanisms for coordination in the brain. Notably, the low-dimensional representations demonstrated maximum predictive accuracy precisely at the action onset, highlighting a just-in-time coordination.
This study emphasizes the synergistic nature of visuomotor coordination in naturalistic behaviors, providing insights into the dynamic interplay of eye, head, and hand movements during reaching tasks in immersive environments.

Key words: low-dimensional representation, visuomotor coordination, ecological validity, virtual reality

Passive BCI Feasibility in Evaluating Knee Exoskeleton Assistance

Khosrotabar, Morteza [1]; Mahmoudi, Asghar [2]; Sharbafi, Maziar [1]

1: Lauflabor Locomotion Lab., Institute of Sports Science, Technical University Darmstadt, Darmstadt, Germany;
2: Institute for Mechatronic Systems, Department of Mechanical Engineering, Technical University Darmstadt, Germany

This research examines the potential of integrating a passive brain-computer interface (BCI) into the individualization of wearable assistive devices, particularly focusing on lower-limb exoskeletons. Lower-limb exoskeletons significantly enhance mobility and improve the quality of life for individuals with lower-limb impairments, while also offering increased strength and reduced effort for those without impairments. The key to maximizing these benefits lies in personalizing the exoskeletons' assistance characteristics to the user's needs. Current study explores the possibility of deducing a user's level of comfort during movement tasks with an exoskeleton based on electroencephalogram (EEG) brain signals. This method represents a novel way of gathering user feedback without requiring conscious control of the device. The experiment employs a knee exoskeleton with a single degree of freedom, modifying stiffness levels to produce varying comfort states. The findings pinpoint specific brain regions, especially the right premotor and supplementary motor cortex, which show notable activity differences under the easiest and most challenging conditions. This validates our hypothesis on the possibility of discerning assistance levels through brain activity. It illustrates the potential of using passive BCI to intuitively adapt assistive technology by interpreting brain signals to understand the user's cognitive state. Such a method could lead to significant advancements in enhancing both the functionality and the user experience of wearable assistive devices.

Key words: Wearable assistive devices, passive Brain-Computer-Interface, Individualization

Motor Attempt Neurofeedback Training Induces Spectral Power Alterations in the Motor Areas of Children with Cerebral Palsy

Kline, Julia; Behboodi, Ahad; Parker, Sheridan; Damiano, Diane

National Institutes of Health, United States of America

EEG neurofeedback training (NFT) is a promising neurorehabilitation that has shown effectiveness in improving motor function post-stroke. We are conducting the first motor attempt (not imagery) NFT study in Cerebral Palsy (CP). Four participants (3 female, mean age 16.1±4.1) with CP completed up to 10 sessions of NFT of ankle dorsiflexion active range of motion and angular velocity. Participant set up included 64-channel EEG (Brain Products) and inertial measurement units on the foot and shank to measure ankle angle. During training, all were instructed to dorsiflex the most involved ankle when cued by a computer screen. Slow movement-related cortical potentials (MRCPs) of the EEG signal (0.05 to 10 Hz) were used to detect intention to move within a 500 ms window preceding movement onset. We trained an LSTM deep learning model to detect peak negativity (PN) of the MRCP signal. During NFT, participants received neuromuscular electrical stimulation of the tibialis anterior when PN was detected, to provide augmented sensory feedback and movement assistance and trigger neuroplasticity via Hebbian association. Outcome measures included temporal-spatial gait measures, peak ankle angle, and event-related spectral perturbation (ERSP) power pre and post training. Data were processed in EEGLAB, including removal of noisy channels and time periods, Artifact Subspace Reconstruction, Adaptive Mixture Independent Component Analysis, and dipole fitting. Each participant demonstrated a different pattern of cortical spectral power change post BCI training, with increased alpha and/or beta event-related desynchronization of the motor areas being a common finding, which may relate to improved ankle and/or gait function.

Key words: Neurofeedback training, EEG, Cerebral Palsy, brain-computer interface, deep learning

A dynamic link between respiration and arousal

Kluger, Daniel [(1)]; Gross, Joachim [(1)]; Keitel, Christian [(2)]

1: University of Münster, Germany;
2: University of Dundee, United Kingdom

Viewing brain function through the lense of other physiological processes has critically added to our understanding of human cognition. Further advances though may need a closer look at the interactions between these physiological processes themselves. Here we characterise the interplay of the highly periodic, and metabolically vital respiratory process and fluctuations in arousal neuromodulation, a process classically seen as non-periodic. In data of three experiments (N = 56 / 27 / 25) we tested for covariations in tidal volume (respiration) and pupil size (arousal). After substantiating a robust coupling in the largest dataset, we further show that coupling strength decreases during task performance compared with rest, and that it mirrors a decreased respiratory rate when participants take deeper breaths. Taken together, these findings suggest a stronger link between respiratory and arousal processes than previously thought. Moreover, these links imply a stronger coupling during periods of rest, and the effect of respiratory rate on the coupling suggests a driving role. As a consequence, studying the role of neuromodulatory arousal on cortical function may also need to consider respiratory influences. In a mobile context, understanding interactions between physiological measures may critically contribute to developping novel performance and vigilance diagnostics.

Key words: pupil diameter, pupil-linked arousal, respiration, LC-NE, brainstem

Cortical dynamics associated with movement preparation in a suprapostural three-directional reaction task

Lehmann, Tim; Chitte, Kshiti; Gokeler, Alli; Büchel, Daniel; Baumeister, Jochen

Paderborn University, Germany

Motivation: Reactive motor actions, concurrently imposing demands on the postural system, inherently involve expeditious movement preparation and initiation. During this phase, the brain is engaged in assessing environmental cues, selecting appropriate motor programs, and setting required parameters for the upcoming movement. However, different movement directions may require unique involvement or collaboration among distributed sensorimotor areas. Thus, the aim was to investigate cortical dynamics associated with movement preparation in a suprapostural three-directional reaction task.
Methods: Seventeen healthy adults (23.7 ± 2.7 years) performed a lower limb reactive balance task with 360 random trials in either anterior, posturomedial or posturolateral direction. A 64-channel mobile EEG (LiveAmp-64, Brain Products, Germany) was used to capture event-related brain dynamics. Reaction times and hip acceleration were quantified using a triaxial accelerometer. For EEG analysis, groupSIFT was used to compute effective connectivity across sensorimotor sources of brain activity.
Results: Reaction times and hip acceleration were significantly different ($p < .01$) between directions. Statistical parametric mapping on the source-level further revealed significant differences in fronto-central (N200, P300), left motor (N100) and inferior parietal (N100) ERPs between directions ($p < .01$). Moreover, movement preparation exhibited distinct patterns of effective connectivity across frontal, central and parietal nodes, contingent upon direction ($p < .01$).
Implications: While ERPs characteristics seemed to align with directional motor aspects, these preliminary findings suggest that the preparation for lower limb movement direction might be attributed to distinct patterns of information flow among fronto-parietal nodes, rather than being governed by a singular cortical area.

Key words: movement preparation, sensorimotor control, directional processing, effective connectivity, groupSIFT

Our Mind at Work: fNIRS-based Encoding and Decoding of Cognitive Load and Learning Dynamics in Simulated Environments

Lingelbach, Katharina [1,2]; Vukelić, Mathias [1]

1: Fraunhofer Institute for Industrial Engineering IAO, Stuttgart, Germany;
2: Applied Neurocognitive Psychology, Department of Psychology, Carl von Ossietzky University, Oldenburg, Germany

Companies striving to remain competitive must reskill their employees through appropriate training environments. Virtual Reality (VR) offers immersive learning experiences that are safe, cost-effective, and customizable to each user's specific needs. To comprehend these needs, Brain-Computer Interfaces (BCIs) allow measuring and interpreting brain activity related to mental states like working memory load. Recent advancements in mobile functional near-infrared spectroscopy (fNIRS) have made it feasible to measure brain activity in real-world BCI applications.
In our research, we examined learning progress and decoding of working memory load with mobile fNIRS in industrial VR training scenarios. A longitudinal study revealed a non-linear relationship between load and the prefrontal cortex (PFC) activation.
During the initial training session, we observed an increase in oxygenated haemoglobin (HbO) in the right PFC with increasing load. However, in the following more challenging session, this pattern diminished, possibly due to excessive (over-)load. In the final session, the positive correlation of load and PFC activation reemerged, suggesting a learning experience. The link between PFC-load correlation and learning was apparent not only in the encoding but also in the decoding. We further investigated different machine-learning feature sets extracted from the fNIRS signals. Our findings indicate that sets combining selected HbO and deoxygenated haemoglobin (HbR) features achieve the highest decoding performance. The HbR peak-to-peak from premotor regions and the right and mid-dorsolateral PFC were most informative.
Our results underscore the potential of mobile fNIRS-based BCIs in real-world applications and offer valuable insights into the neural underpinnings of working memory load and learning.

Key words: Mobile Functional Near-infrared Spectroscopy (fNIRS), Working Memory, Learning, Brain-computer Interface (BCI), Virtual Reality (VR)

Impact Study of Meditation on Brain and Stress Using EEG Signals

Lotia, Siddharth; Banshpal, Ishan

IIIT Bangalore, India

This work explores the dynamic interplay between meditation, stress reduction, and electroencephalography (EEG)- based measurements. Our primary aim is to discern and characterize the impact of meditation on brain activity and its potential role in stress reduction. Leveraging EEG data from both meditators and non-meditators during meditation and rest states, we employ signal processing techniques and a machine learning-based classifier for differentiation. Subsequently we dive deeper into various bands of EEG signals, our study focuses on the comparative analysis of alpha, beta, and theta power values as key features extracted from EEG signals. Our findings aim to illuminate specific neural patterns associated with meditation, addressing whether meditation induces a shift from stress-related beta power activity to a non-stress state and potentially enhances relaxation through increased alpha and theta power activities. We explore both time domain and frequency domain features By investigating these EEG-derived features, we contribute to a nuanced understanding of the physiological mechanisms underlying meditation-induced stress reduction.

Key words: Machine Learning, Meditation, Electroencephalography, Signal Processing

Cortical markers of cognitive control in Parkinson's disease during obstacle avoidance: a mobile EEG study

Magda, Mustile [1,2]; Dimitrios, Kourtis [2]; Martin G, Edwards [1]; Simon, Ladouce [3]; Daniele, Volpe [4]; Manuela, Pilleri [4]; Elisa, Pelosin [5]; Gemma, Learmonth [2]; David I, Donaldson [6]; Magdalena, Ietswaart [2]

1: Université catholique de louvain, Belgium;
2: Psychology, Faculty of Natural Sciences, University of Stirling, Stirling, UK;
3: Department of Brain and Cognition, Leuven Brain Institute, KU Leuven, Leuven, Belgium;
4: Fresco Parkinson Center, Villa Margherita, S. Stefano Riabilitazione, Vicenza, Italy;
5: Ospedale Policlinico San Martino, IRCCS, 16132 Genova, Italy;
6: School of Psychology and Neuroscience, University of St Andrews, St. Andrews, UK

The loss of the ability to control gait represents one of the main risk factors for falling and hospitalisation in elderly and in patients with neurological disorders, such as Parkinson's disease. Gait impairments are particularly frequent in Parkinson's disease patients who exhibit reduced gait speed, shorter stride length and poor postural control. These disturbances result in unstable gait control, making daily life activities very challenging and risky, such as when they have to overcome obstacles. Despite the extensive literature on gait problems in Parkinson's disease, to date, cortical markers of cognitive and motor control during walking in Parkinson's disease have been investigated only through tasks with relatively low ecological validity. To better understand cognitive and neural processes underlying gait control, it is necessary to target natural movements in circumstances that resemble real life scenarios. In the present talk, I will present an investigation of the neural correlates of naturalistic obstacle avoidance in Parkinson's disease using the mobile EEG. We examined 14 patients with Parkinson's disease and 17 neurotypical control participants. Brain activity was recorded while participants walked freely, and while they walked and adjusted their gait to step over expected or unexpected obstacles displayed as images on the floor. The EEG analysis revealed attenuated cortical activity in Parkinson's patients, in both theta (4-7 Hz) and beta (13-35 Hz) frequency bands, before and after an obstacle avoidance. This reduced cortical activity suggests a deficit of motor-cognitive control in Parkinson's disease involving impairments in the proactive and reactive strategies used to avoid obstacles while walking.

Key words: mobile EEG; Parkinson's disease; obstacle avoidance; cognitive processes

The Art of Brainwaves: A Survey on Event-Related Potential Visualization Practices

Mikheev, Vladimir; Skukies, Rene; Ehinger, Benedikt

University of Stuttgart, Germany

The field of M/EEG research has witnessed significant advances, such as the integration of virtual reality and the emergence of mobile EEG setups. Virtual reality setups provide more naturalistic environments, and mobile EEG systems enable data collection in real-world settings. However, this paradigm shift adds new levels of complexity to the analysis and visualization of EEG data: increase of data dimensionality and complex statistical models. Both make understanding the data and visualizing it much more complicated.

This study explores the user experience of a typical EEG practitioner attempting to visualize ERPs. We conducted an online survey of approximately 200 respondents, including both novices and experts in the field of EEG. The results shed light on the most used tools for ERP visualization, preferred tool features, most common visualization challenges, and awareness of issues related to color and error bars in graphs.

Our survey results indicated that tools such as EEGLAB, FieldTrip, and ERPLAB were best known, along with MNE and Brain Vision Analyzer. We found that several common problems were faced by practitioners during ERP visualizations: adding uncertainty to ERP plots, color in butterfly plots, channel highlighting in topoplots were among the common challenges. Researchers valued features such as publishable plots, reproducibility, and speed, and were skeptical of interactive data selection. Many were unaware of color map issues, and 40% omitted error bars in published ERP plots. The findings of this study provide valuable guidance for the development of effective visualization tools (especially for Mobile EEG) and improved research practices.

Key words: Electroencephalography, Event-related potentials, Visualization, User experience survey, EEG software, Visualization awareness.

Embodying an industrial robotic arm: a multimodal perspective on brain and motor patterns

Nenna, Federica [1,2]; Gramann, Klaus [3]; Gamberini, Luciano [1,2]

1: University of Padova, Department of General Psychology, Padova, Italy;
2: Human Inspired Technology (HIT) Center, University of Padova, Padova, Italy;
3: Biological Psychology and Neuroergonomics, Technical University of Berlin, Berlin, Germany

In the industrial robotics field, Virtual Reality (VR) represents an attractive option to let workers teleoperate robots in immersive environments. In VR, human-robot interfaces can leverage intuitive body motion and physical actions, namely Body-Machine Interfaces, which have various advantages: they can potentially trigger mechanisms of embodiment, enhance teleoperation transparency and telepresence, and eventually improve motor control and work performance. Despite their evident implications, to our knowledge, an in-depth investigation addressing these mechanisms multimodally is still missing.
In this research, by combining knowledge from robotics, psychology, neuroscience, human factors, and computer science fields, we comprehensively addressed human behavioral and cognitive dynamics during a VR-based teleoperation of the industrial robotic arm UR10e. Participants embodied the robot from a first-person perspective in VR. They guided it through a high-precision teleoperation task under various manipulations (a 500ms temporal delay and a 20cm offset between the own arm and the robotic arm). A MoBI set-up allowed concurrent recordings of the human arm's motor trajectories and the underlying neural dynamics via EEG, targeting particularly μ-ERD over centro-parietal brain areas.
By analyzing the motor pattern together with ERSPs and self-report data, this research provides a comprehensive overview of the complex human dynamics underlying embodied teleoperations in VR.

Key words: Virtual Reality, Teleoperation, EEG, Industrial Robotics, Multimodal Assessment, MoBI

Reduction of Cadence Artifact in Mobile EEG

Nonte, Michael William [1]; Dang, Thomas Van [1];
Adair, Devin Killion-Petty [2]; Yu, Alfred [2]; Hairston, William David [2]

1: DCS Corp, United States of America;
2: U.S. Army Combat Capabilities Development Command-Army Research Laboratory, United States of America

Motion-related artifacts are a persistent problem in mobile electroencephalography (EEG) signal quality. Walking while recording EEG can induce an artifact at the cadence frequency and several of its harmonics. There are many widely used methods to remove motion artifact. While these methods have been shown effective in removing artifact, they can also distort the neural signal. In this work, we demonstrate an alternative approach using anti-static devices to eliminate cadence artifact so that artifact removal during preprocessing is no longer necessary.
Participants performed treadmill walking, paced overground walking, and a mobile virtual reality visual oddball task. Each task was performed once with and once without the use of anti-static devices. Participants wore an anti-static wristband while walking on the treadmill and anti-static heel straps with grounded flooring during overground walking.
Signal-to-noise ratio in the mobile VEP task was computed as average P300 peak height to inter-trial standard deviation. Noise reduction was computed as the EEG signal power ratio at cadence frequencies during walking to the same frequencies during standing. SNR was significantly higher ($p < 0.05$) and noise was significantly lower ($p < 0.05$) when anti-static devices were used.
We have demonstrated a new approach to motion artifact removal that allows for the capture of clean neural signals in mobile environments without the risk of contaminating signals during processing. This will lead to a dramatic change in the time spent processing EEG data from mobile studies and a proliferation new EEG research in mobile environments.

Key words: Mobile EEG, Motion Artifact, VR

Examining Cortico-Muscular Connectivity Methods on Mobile Brain Imaging Data: A Comparative Study with Parkinson's Disease Patients

Omejc, Nina [1,2]; Peskar, Manca [3,4]; Kalc, Miloš [3,5]; Džeroski, Sašo [1]; Manganotti, Paolo [6]; Gramman, Klaus [4]; Marusic, Uros [3,7]

1: Jožef Stefan Institute, Department of Knowledge Technologies, Ljubljana, Slovenia;
2: Jožef Stefan International Postgraduate School, Ljubljana, Slovenia;
3: Science and Research Center Koper, Institute for Kinesiology Research, Koper, Slovenia;
4: Department of Psychology and Ergonomics, Faculty V: Mechanical Engineering and Transport Systems, Technische Universitat Berlin, Berlin, Berlin, Germany;
5: Faculty of Medicine, University of Maribor, Maribor, Slovenia;
6: Clinical Unit of Neurology, Department of Medicine, Surgery and Health Sciences, Trieste University Hospital-ASUGI, University of Trieste, Trieste, Italy;
7: Department of Health Sciences, Alma Mater Europaea Evropski Center Maribor, Maribor, Slovenia

To capture the relationship between the cortico-cortical and cortico-peripheral regions, as well as evaluate the brain functioning collectively, connectivity analysis has been progressively used. This work aims to evaluate the usability and temporal resolution of cortico-muscular connectivity methods by analyzing simultaneously recorded 128-channel electroencephalographic (EEG) and 64-channel high-density electromyographic (EMG) data from 40 participants, encompassing both healthy individuals and those with Parkinson's disease.

Participants underwent measurements during resting state (with eyes open) and while engaged in two mobile tasks – an isometric knee extension and a semi-tandem stance. EMG electrodes were placed on Vastus lateralis and Tibialis anterior, respectively. The analysis pipeline involves preprocessing steps such as filtering (0.5 Hz to 80 Hz, with additional line noise removal), manual cleaning, channel interpolation, average re-referencing, and independent component analysis decomposition. Subsequently, the EEG data is projected onto 68 cortical regions defined by the Desikan-Killiany atlas, employing the Standardized Low-Resolution Tomography (sLoreta) method. Analogously, EMG data is decomposed to extract motor unit activity using the Convolution Kernel Compensation method.

Following data preparation, connectivity analysis will be conducted, with a focus on comparing standard coherence analysis to more advanced transfer entropy and hidden Markov modeling (using Gaussian observation model) methods, both on channel-level and source-projected data. Additionally, the study will explore variations in the time intervals over

which the connectivity methods are calculated. The critical comparison of three distinct connectivity methods on cortico-muscular data will help in advancing further connectivity analyses.

Key words: MoBI, EEG, EMG, cortico-muscular connectivity, Parkinson's disease

Scaling EEG Mu rhythms from static laboratory to real-world paradigms

Parada, Francisco [1]; **Grasso-Cladera, Aitana** [2]

1: Universidad Diego Portales, Chile;
2: Institute of Cognitive Science, Osnabrück University. Osnabrück, Germany.

This study explores the neural dynamics underlying the observation and execution of hand gestures, from static laboratory settings to real-world natural behavior using the rock-paper-scissors game (RPS). We examined electroencephalography EEG Mu rhythm (μ) in 23 participants (16 women, age range 18-50 years) during three task conditions: Gesture Identification (Baseline), Simulated Interaction (vs. Computer), and Simulated Interaction (vs. Human). A fourth real-world interaction task was conducted where pairs played the game in the real-world wearing a hyperscanning EEG/ECG system (MoBI).
We anticipated distinct μ patterns corresponding to the different gestures (i.e., rock, paper, scissors) in both observation and execution phases. This is expected to reflect the brain's mirror neuron system activity, crucial in action understanding and imitation. The study also hypothesized pronounced μ suppression during both observed and executed gestures, indicative of sensorimotor cortex engagement.
Wavelet-based time-frequency analysis was implemented to quantify μ suppression. Analyses were focused over typical μ sensors (C3, Cz, C4) reported in the literature, overlying the motor cortex. Results show as the motor action scalates towards the real-world μ desynchronization increases, offering insights into the neural engagement levels based on the social context. We interpret stronger desynchronization as reflecting stronger inhibition of unrelated motor activity and/or sensory processing, allowing neural resources to focus on planning and preparing the socially-relevant intended movements.
As RPS is often used by therapists to help diagnose social cognition conditions, our research contributes to the broader understanding of the neural mechanisms underlying social cognition and empathy.

Key words: Scalable design, Mu rhythms (μ), Real-world task, EEG, Hyperscanning

Low-Dimensional Parameter Microstate analysis applied in Arts & Urbanism

Parada, Francisco [1,2]; Rossi, Alejandra [1,2]; Pedraza, Pedro [1,3]; Maza, Valentina [3]; Zúñiga, Carolina [1,4]

1: Universidad Diego Portales, Chile;
2: Centro de Estudios en Neurociencia Humana y Neuropsicología;
3: Pontificia Universidad Católica de Chile, Chile;
4: Laboratorio Digital UDP

An innovative transdisciplinary approach to understanding well-being, health, and disease states, grounded in the Embodied, Extended, Embedded, and Enactive (4E) theories of cognition is presented. The goal is to describe patterns formed through modifications in cortical neuron connections due to real-world experience, which are specific to each person. The study employs a single-subject modeling approach, where parameters are designed to capture single-trial information like stimuli/experiences/real-world characteristics. Importantly, model residuals are analyzed to reveal latent, complex dynamics underlying EEG data, offering a nuanced understanding of brain activity. We called this metric the Lower-Dimensional Parameter (LDP).
LDP is computed by regressing EEG data using hypothesis-relevant properties and computing microstates from modeled residuals. LDP-Microstates are then computed for a multi-level analysis.
Three distinct datasets will be presented. The first involves a virtual walk over the Maipo River, experienced from two perspectives to highlight differences in self-experience. The second dataset contrasts video narrations within an immersive environment against the same videos in traditional laboratory settings. Finally, the third dataset offers a three-layered single-case study of artistic experiences, including a) recorded music, b) a private concert, and c) a public concert by the same artist experienced by the same participant.
Data for all datasets were collected using a 32-sensor EEG/ECG system, ensuring detailed and high-quality neurophysiological recordings. This work represents a groundbreaking step in real-world neuroscience of artistic/aesthetic experiences, offering deeper insights into the human experience as influenced by diverse environmental contexts.

Key words: Real-World, Hyperscanning, Neuroaesthetics (music and art); Neurourbanism (natural space)

Understand the effectiveness of a non-invasive and non-drug approach to improve postural control using mobile EEG

Paramento, Matilde [1]; Passarotto, Edoardo [1]; Agostini, Michela [1]; Contessa, Paola [2]; Formaggio, Emanuela [1]; Ceolin, Chiara [1]; Sergi, Giuseppe [1,2]; Masiero, Stefano [1,2]; Rubega, Maria [1]

1: University of Padova, Padova, Italy;
2: Padova University Hospital, Padova, Italy

Falls are a common health problem with serious consequences in older adults due to age-related deterioration of biological systems. Evidence-based interventions can reduce the occurrence of falls. NeuroMuscular Taping (NMT) is designed to stimulate myofascial structures through the skin and improve proprioception. The aim of this study is to evaluate the effectiveness of NMT in improving postural control. NMT was applied to specific muscles in 5 older female adults at risk of falling (i.e. with mild osteoporosis). Gait and balance were assessed by a physiotherapist at baseline (T0) and after 3 weeks of NMT treatment (T1) using the Mini-BESTest. High-density EEG data were collected during the sensory orientation tasks of the Mini-BESTest (eego™sports, AntNeuro). The power spectrum (P) in the alpha band (8-13 Hz) was calculated in the source space while standing on a foam surface for 30 s with eyes closed (EC) and eyes open (EO) at T0 and T1. The change in alpha power ((P_EO-P_EC)/P_EC) between T0 and T1 was assessed by means of a mixed effects regression model and was statistically significant ($p<0.01$). Observing the results, the weaker posterior alpha power during EO than EC, indicating the enhancement of cortical sensorimotor information processing when visual input was available, is more evident at T0. This result suggests that the elderly improved their postural coordination and stability at T1 (as evidenced by the average improvement of 2.6 points in the Mini-BESTest score), which reduced the difference in cortical activations between EO and EC.

Key words: EEG, balance, elderly, falls, Mini-BESTest

Body Schema alterations in adolescent idiopathic scoliosis: evidence from a target-reaching task

Passarotto, Edoardo [1]; Paramento, Matilde [1]; Contessa, Paola [2]; Maccarone, Maria Chiara [1]; Agostini, Michela [1]; Lazzari, Valentina [2]; Rubega, Maria [1]; Masiero, Stefano [1,2]; Formaggio, Emanuela [1]

1: University of Padova, Padova, Italy;
2: Orthopedic Rehabilitation Unit, Padova University Hospital, Padova, Italy

The pathophysiology of adolescent idiopathic scoliosis (AIS) is not fully understood. A better understanding of the changes in brain activity associated with movement during a target-reaching task may help to reveal alterations in body schema. The task assesses the influence of the body schema on movement planning. The performance of six subjects with AIS was quantitatively assessed using mobile electroencephalography (EEG, eego™sports, AntNeuro) and marker-based stereophotogrammetry. Subjects performed the task after observing the experimenter touching one of the 10 targets displayed at different positions on the board. They were instructed to reach the same point before returning to the starting position, keeping their eyes closed. The Euclidean distance between the coordinates of the two points (experimenter- and subject-selected) was calculated for each target as a measure of the precision of task performance. A time-frequency event-related synchronization/desynchronization (ERS/ERD) approach was used to investigate where movement-related decreases in power were localized. In subjects with a right main curve, ERD in alpha band was observed over the sensorimotor area ipsilateral to the movement performed with the right hand, reflecting abnormal processing of sensorimotor information. A mixed-effects regression model showed a significant asymmetry in task performance between hands, with the right hand having a significantly greater horizontal deviation than the left one ($p < .05$). This study suggests new perspectives for evaluating brain activity and assessing altered body schema using quantitative EEG to better understand the planning and execution of movement.

Key words: EEG, adolescent idiopathic scoliosis, target reaching, body schema

Cognitive-Motor Interference in older adults with or without Parkinson's disease investigating gait-phase spectral modulation

Peskar, Manca [1,2]; Gramann, Klaus [2]; Manganotti, Paolo [3]; Marusic, Uros [1,4]

1: Institute for Kinesiology Research, Science and Research Centre Koper, Slovenia;
2: Biological Psychology and Neuroergonomics, Technische Universitaet Berlin, Germany;
3: Clinical Unit of Neurology, Department of Medicine, Surgery, and Health Sciences, University of Trieste, Trieste, Italy;
4: Department of Health Sciences, Alma Mater Europaea - ECM, Maribor, Slovenia.

Human gait, though highly automated, relies on cortical resources, as evidenced by beta-band (β; 18-30Hz) desynchronization and gait-phase-dependent low gamma-band (γ; 24–40 Hz) modulation in the central sensorimotor cortices. In Parkinson's disease (PD), β hypersynchrony is linked to bradykinesia but has not been studied noninvasively during natural overground walking and simultaneous cognitive tasks. This study aimed to explore mechanisms of full-body movement execution when attention is split between cognitive and motor tasks, mimicking real-life scenarios in PD patients.
Sixteen PD patients (mean age 62.9) and 16 healthy controls (mean age 64.1) completed self-paced overground walking in wide (80 cm) and narrow (40 cm) lanes under both single-task (ST) and dual-task (DT) conditions, while EEG and full-body kinematics were recorded. Nonparametric cluster-based permutation testing analyzed gait-phase-dependent spectral modulation.
Healthy controls walked faster than PD patients ($F(1, 32)=7.4$, $p=.01$), and ST walking was faster than DT walking ($F(1, 32)=47.7$, $p<.001$). Greater β - and low-γ band synchronization was observed in PD patients vs. healthy controls and during DT vs. ST walking, at the dual-support phase of the gait cycle. This effect was more pronounced in narrow-lane walking.
These findings further support the overlapping cortical sources involved in motor and cognitive control. Additionally, the observed effects in PD patients could point to impaired somatosensory (proprioceptive) processing arising as a result of neuropathy. These non-invasively obtained insights could inform interventions and fall prevention strategies for PD patients.

Key words: Mobile Brain/Body Imaging (MoBI), EEG, Parkinson's Disease

Compensation Related Utilization of Neural Circuits (CRUNCH) of Electrocortical Activity during Walking on Terrain Unevenness

Pliner, Erika [1]; Liu, Chang [2]; Salminen, Jacob [2]; Richer, Natalie [3]; Hwang, Jungyun [2]; Clark, David [2,4]; Seidler, Rachael [2]; Hass, Chris [2]; Manini, Todd [2]; Cruz-Almeida, Yenisel [2]; Ferris, Daniel [2]

1: University of Utah, United States of America;
2: University of Florida, United States of America;
3: University of Winnipeg, Canada;
4: Malcom Randall VA Medical Center, United States of America

Mobility decline affects 40% of older adults [1]. Understanding the brain processes of walking with age can improve the diagnosis and preventative approaches of mobility decline. We propose the brain activity of walking to follow the Compensation Related Utilization of Neural Circuits Hypothesis (CRUNCH). This hypothesis comprises of 1) an over-recruitment of brain resources at lower task difficulty and 2) a ceiling effect (reduction) of available brain resources, resulting in a 'crunch' of the brain activation range with age [2].
We assessed the brain dynamics of 31 younger (aged 20-40 years) and 53 older (aged 60+ years) adults walking on uneven terrain of varying difficulty. Participants were asked to complete 3-minute walking trials, totaling to 48-minutes of treadmill walking. Participants walked at a participant-tailored speed on 4 terrain conditions (details previously reported [3]). Brain dynamics were recorded from a custom 240 dual-layer (120 scalp and 120 noise electrodes) electroencephalogram (EEG) system. EEG data underwent cleaning and source localization processes (details previously reported [4]).
Seven brain source clusters were identified in younger and older adults using K-means. Younger adults demonstrated a greater reduction in alpha and beta spectral power than older adults with increasing task difficulty in sensorimotor and posterior parietal areas. This increased range in brain activity in younger adults and relative 'crunch' in brain activity range in older adults, supports the CRUNCH framework for walking.

[1.] Musich et al. (2018) Geriatric Nursing. [2.]Clark et al. (2020) Front. Aging Neuroscience. [3.] Downey et al. (2022) PlosOne. [4.] Liu et al. (2023) bioRxiv Preprint.

Key words: Aging, gait, cognitive resources, source localization, component analysis

CMI and aging: Dual-task costs in walking speed are reflected in changes in alpha and beta power in older and younger adults

Protzak, Janna [1]; Gramann, Klaus [2]

1: Emory Univerisity, USA;
2: TU Berlin, Germany

Walking can be an essential motor task that contributes to independent living. However, with age-related decline, even simple locomotor tasks such as walking at a comfortable pace while scanning the environment for obstacles can become challenging. We examined how walking performance changed when transitioning from single-task overground walking on a 10m track to dual-task walking with an additional visual discrimination task in two age groups: younger adults (<35 years, n=17) and older adults (>65 years, n=14). We analyzed motor performance and EEG frequency patterns over motor cortex areas to gain a better understanding of the neural mechanisms that modulate gait behavior. During dual-task walking, both groups exhibited slower walking speeds and longer stride times compared to single-task walking. Additionally, older adults demonstrated greater gait variability than younger adults. The EEG power spectral density pattern of the single and dual task walking periods was separated into aperiodic and periodic activity using the fooof-toolbox (Donoghue et al., 2020). For the aperiodic activity, we observed lower offsets in older adults compared to younger adults. Additionally, the slope increased from single-task walking to dual-task walking in both groups. Regarding the periodic activity, we found changes in alpha and beta power from single-task walking to dual-task walking to be related to walking speed.
Our results provide new insights into age-related differences in the power spectrum during natural overground walking. Additionally, we propose a simple EEG metric that reflects dual-task costs on walking speed.

Key words: aging, gait, dual-task, EEG, PSD

Exploiting eye blink activity-related EEG to measure cognitive workload in the wild

Reiser, Julian Elias; Alyan, Emad; Arnau, Stefan; Wascher, Edmund

Leibniz Research Centre for Working Environment and Human Factors, Germany

In the field of neuroergonomics, our goal is to gain a better understanding of cognitive processes of individuals within their actual work environments. However, most research remains confined to the controlled settings of laboratories, using abstract stimuli and restricting participant actions to minimal movements and button presses. To advance our understanding of cognition in work settings, we examined cognitive processing following natural bodily behaviors — specifically, spontaneous eye-blinking — in the absence of external stimulation.
Historically, eye activity has been largely overlooked in neurophysiological analysis, considered an artifact rather than a source of meaningful data. Yet, recent findings suggest that spontaneous blinking correlates with key moments in information processing, aiding in the segmentation of both visual and auditory information streams. To explore the cognitive dynamics after spontaneous blinking, we reanalyzed datasets from prior real-world simulations, including driving and control room operations.
Through the calculation of blink-event related potentials (bERPs), we investigated cognitive processing in scenarios with varying workload conditions. Our results reveal notable shifts in ERP component amplitudes, similar to stimulus-evoked ERPs, with condition-specific variations in components linked to attention and workload (P1, N2, P3).
These findings propose that bERPs are a valuable tool for assessing real-world workload levels, offering insights without disrupting the natural flow of work-related activities. Utilizing these methods may enable us to pinpoint tasks that are cognitively demanding within work processes and develop appropriate interventions.

Key words: mobile EEG, eye-blink-related potentials, neuroergonomics, natural cognition, eye activity

Towards the standardization of BCI paradigms to design plug-and-play neurogames

Romani, Michele [1,2]**; Guger, Christoph** [1]**; Turchet, Luca** [2]

1: g.tec Medical Engineering gmbh, Austria;
2: University of Trento

Recent achievements in the production of reliable and portable Brain-Computer Interfaces (BCIs) are leading to an increasing interest towards non-clinical applications such as video games, targeted to a wider audience. In an active EEG-based BCI, Event-Related Potentials (ERP) and Visually Evoked Potentials (VEP) can be employed in stimulation paradigms to provide users with accurate brain input after a short calibration. This input can be used to build BCI-controlled "neurogames". To date, only a few studies considered and compared the performance of different BCI paradigms under the same task conditions, an essential step for standardizing guidelines to build general-purpose neurogames. In a previous study, we proposed a framework to develop and benchmark online BCI applications using 4 different combinations of stimulation paradigms and event-related potentials within the Unity game engine. This paper proposes a novel plug-and-play Unicorn device with 4 EEG dry electrodes, which is used in two configurations: with standard flat screen and paired with a Meta Quest head-mounted display. A study was conducted with 6 healthy participants who were asked to perform a selection task with 4, 6 and 8 classes for each stimulation/potential combination available in the framework. The goal of the benchmark is twofold: firstly, comparing the performance of the BCI system using only 4 electrodes against the 8 electrodes configuration from a previous study; secondly, comparing the performance between the flatscreen and the virtual reality applications.

Key words: BCI, Gaming, EEG, VR, MachineLearning

You: Quantified - A web application for real-time visualization and sonification of MoBI data

Romero, Esteban [1,2]; Chen, Phoebe [1]; Shevchenko, Yury [3]; Zerwas, Felicia [1]; Porteous, Franck [1]; Montgomery, Sean [4]; Sargent, Kaia [5]; Chatufale, Girija [1]; Ochoa, Xavier [1]; Matuk, Camilia [1]; Dikker, Suzanne [1]

1: New York University;
2: Tecnológico de Monterrey;
3: Universität Konstanz;
4: Connected Future Labs;
5: University of California, Los Angeles

The "Quantified Self" movement has become a billion-dollar industry, with millions of people wearing devices to track their own behavior and neurophysiology. It has fueled innovations in wearable biosensor technologies and has permeated diverse industries and aspects of society. Therefore, as real-world data collection and community science approaches gain ground, there is a need for tools that provide communities with a humanistic perspective on data –what their data can and cannot say– to improve data literacy and make informed decisions about ownership and privacy. We tackle the challenges often involved in collecting and operating multi-stream physiological data by both scientists and non-researchers alike with a user-friendly browser-based approach that streamlines the connection of MoBI data to interactive, customizable, and real-time audiovisual experiences. You: Quantified is a web-based application that can receive data from various biosensors, derive metrics from camera and microphone feeds, and supports the widely used LSL (lab streaming layer) system. The tool offers recording and playback capabilities, and it integrates the data streams into a code sandbox powered by P5.js, a commonly used JavaScript library for users to create custom and interactive data representations. You: Quantified is designed to be open source and web-based to allow for a wide range of possible implementations, such as real-world MoBI experience sampling research, BCI (brain-computer-interface) applications, and data literacy programs. As such, the platform can be a gateway for researchers, developers, communities, artists, therapists, and teachers to develop, share and participate in unique and informative experiences built on MoBI data.

Key words: wearable biosensors, data literacy, creative coding, ease-of-use

Towards understanding auditory perception at workplaces using mobile EEG

Rosenkranz, Marc [1]; Haupt, Thorge [1]; Jaeger, Manuela [1]; Bleichner, Martin G. [1,2]

1: Neurophysiology of Everyday Life Group, Department of Psychology, Carl-von-Ossietzky University of Oldenburg, Oldenburg, Germany;
2: Research Center for Neurosensory Science, Carl-von-Ossietzky University of Oldenburg, Oldenburg, Germany

In demanding work situations, such as performing a surgery, the soundscape can be a burden for personnel. While background noise in the operating room has long been identified as a stressor for medical staff, the exact effects are difficult to quantify. Surgeons often find the soundscape disturbing, yet this is not immediately reflected in diminished surgical performance, suggesting that performance is not sufficient for measuring the individual burden of noise. To address this gap, we explore the possibility to use mobile electroencephalography (EEG) to capture sound processing continuously and non-intrusively during surgical procedures to understand when sound becomes a burden.
We gradually developed our empirical approach to study medical staff in the operating room. Frist, to establish that meaningful data could be obtained in dynamic, activity-rich environments, we used a complex audio-visual-motor task (3D Tetris) to investigate the perception of realistic operating room soundscapes. Second, participants performed short laparoscopic tasks on a surgical simulator while exposed to complex soundscapes under two different workload conditions. We found a clear relationship between the EEG and the soundscape, which changed over time but was not dependent on the workload manipulation. Finally, we compared different approaches to characterize the soundscape, and studied their effect on predicting the neural response. Taken together, we made important steps towards using mobile EEG as a tool to study individual sound perception in the operating room and other workplaces.

Key words: mobile EEG, auditory processing, ERP, temporal response function (TRF), neuroergonomics

Electrocortical Dynamics of Older Adults Walking at Different Speeds and on Varied Terrain Difficulties

Salminen, Jacob [1]; Liu, Chang [1]; Downey, Ryan J. [1]; Pliner, Erika M. [2]; Richer, Natalie [3]; Hwang, Jungyun [4]; Clark, David J. [4,5]; Seidler, Rachel D. [6,7,8]; Hass, Chris J. [6]; Manini, Todd M. [9]; Cruz-Almeida, Yenisel [10,11,12]; Ferris, Daniel P. [1,8]

1: Department of Biomedical Engineering, University of Florida, Gainesville, FL, USA;
2: Department of Mechanical Engineering, University of Utah, Salt Lake City, UT, USA;
3: Department of Kinesiology and Applied Health, University of Winnipeg, Winnipeg, Canada;
4: Department of Neurology, University of Florida, Gainesville, FL, USA;
5: Brain Rehabilitation Research Center, Malcom Randall VA Medical Center, Gainesville, FL, USA;
6: Department of Applied Physiology and Kinesiology, University of Florida, Gainesville, FL, USA;
7: Norman Fixel Institute for Neurological Diseases, University of Florida, Gainesville, FL, USA;
8: McKnight Brain Institute, University of Florida, Gainesville, FL, USA;
9: Department of Health Outcomes and Biomedical Informatics, University of Florida, Gainesville, FL, USA;
10: Department of Community Dentistry and Behavioral Science, University of Florida, Gainesville, FL, USA;
11: Pain Research and Intervention Center of Excellence, University of Florida, Gainesville, FL, USA;
12: Department of Epidemiology, University of Florida, Gainesville, FL, USA

Aging decreases mobility and gait stability in humans. Compared to younger adults, older adults have poorer vision, reduced somatosensation, less precise proprioception, and weaker muscles (Chalmers & Knutzen, 2000; Franz et al., 2015; Marigold & Patla, 2008). We know some biomechanical and subcortical contributions to reduced automaticity of walking exhibited by older adults, but our understanding of the cortical contributions is lacking (Boyer et al., 2017; Clark, 2015; Sato & Choi, 2022). We recorded high-density EEG of older adults (n=55, ages 65-90 years) walking at different speeds and on terrain difficulties to understand electrocortical contributions to the control of gait. We used a sacral IMU and foot force sensors to determine gait events. We extrapolated electrocortical activity from scalp level EEG using subject-specific conductivity head models and independent component analysis (Gonsisko et al., 2023; Liu et al., 2023). We observed electrocortical activity in the sensorimotor, posterior parietal, and mid-posterior cingulate. A linear mixed effects model determined the effect of terrain difficulty on mean power in theta (4-8 Hz) and beta (13-30 Hz) bands for each brain region (alpha=0.05). With increasing terrain difficulty, we observed decreases in beta power

(i.e., increased calculations (Neuper & Pfurtscheller, 2001)) in sensorimotor (Cohen's f2 = 0.45), posterior parietal (Cohen's f2 = 0.56) and mid-posterior cingulate (Cohen's f2 = 0.46). With increasing walking speed, theta power increased (i.e., increased sensory influx (Richer et al., 2024)) in sensorimotor (Cohen's f2 = 0.19), posterior parietal (Cohen's f2 = 0.053), and mid-posterior cingulate (Cohen's f2 = 0.20). Our results suggest that walking on uneven terrains and at different speeds is concurrent with a network of brain areas with broad band electrocortical modulations (Cohen's f2 Levels: small>0.02, medium>0.15, and large>0.35).

Key words: high-density EEG, clinical, aging, neuroscience

Transcutaneous Auricular Vagus Nerve Stimulation Improves Gait Characteristics in Parkinson's Disease Patients

van Midden, Vesna Marija [1,2]; Simončič, Urban [3,4]; Pirtošek, Zvezdan [1,2]; Kojović, Maja [1,2]

1: Department of Neurology, University Medical Centre Ljubljana, Ljubljana, Slovenia;
2: Medical Faculty, University of Ljubljana, Ljubljana, Slovenia;
3: Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia;
4: Jozef Stefan Institute, Ljubljana, Slovenia

Background:Transcutaneous electrostimulation of the auricular branch of the vagal nerve (taVNS) has shown promise in modulating dysfunctional neuromodulatory networks associated with Parkinson's disease (PD). This study aims to evaluate the effects of taVNS at 25Hz (taVNS25) and 100Hz (taVNS100), as well as sham earlobe stimulation (sVNS), on gait characteristics in advanced PD.

Methods: 30 PD patients (mHY 2.5-4) participated in a double-blind, within-subject randomized trial. Gait characteristics, including Arm Swing Velocity, Arm Range of Motion, Stride Length, Gait Speed, Arm Range of Motion Asymmetry, Anticipatory Postural Adjustment (APA) duration, APA First Step Duration, APA First Step Range of Motion, and turn-related parameters, were measured using inertial motion sensors. Generalized mixed models were used for analysis.

Results: Compared to sVNS, taVNS100 showed improvements in arm swing velocity ($p = 0.030$) and stride length ($p = 0.027$), while reducing APA duration ($p = 0.050$). taVNS25 resulted in increased stride length ($p = 0.024$) and gait speed ($p = 0.021$), along with decreased double 360° turn duration ($p = 0.039$).

Conclusions: This study demonstrates that taVNS has a frequency-specific effect on gait in PD patients. Both taVNS100 and taVNS25 improved stride length, with taVNS100 also improving arm swing velocity and taVNS25 enhancing gait speed and turn duration. These findings suggest that taVNS could be an effective adjunct treatment for gait impairments in advanced PD. Further research is necessary to explore the underlying mechanisms and long-term effects of taVNS for PD management.

Key words: taVNS, Parkinson's disease, objective gait measures

Machine Learning for multimodal wearable fNIRS–bridging the gap between neuroscience and everyday environments

von Lühmann, Alexander

Technische Universität Berlin - BIFOLD, Germany

Advancements in system design and signal processing have established functional Near Infrared Spectroscopy (fNIRS) as a cost-effective and practical modality for routine, increasingly unconstrained, and mobile brain imaging. The shift towards experimental studies and applications in dynamic, complex, and multisensory real-world environments offers numerous opportunities to progress research in brain function and dysfunction. However, transitioning from well-controlled laboratory settings to the less predictable environment of the everyday world presents a range of challenges encompassing signal acquisition, processing, data fusion, and biomarker extraction. A key challenge in these contexts is to extract hemodynamics with sufficient contrast, such as distinguishing evoked from non-evoked activity and cerebral from non-cerebral activity. At the Intelligent Biomedical Sensing (IBS) Lab at Technische Universität Berlin, BIFOLD, we approach this issue by developing novel wearable neurotechnology and data-driven sensor-fusion methods that leverage multiple signal modalities. This presentation will examine recent advancements towards mobile brain-imaging using fNIRS. We will discuss the data science challenges that need to be addressed and demonstrate how we have begun to tackle them in "Cedalion" - a novel toolbox for data driven multimodal fNIRS analyis.

Key words: fNIRS, HD DOT, neuroscience in the everyday world, multimodal, Machine Learning

Finding Waldo: Neurophysiological Correlates of Target Detection in Cluttered Visual Scenes

Wagner, Johanna [1,2]; Chitu, Alin [1]; Zander, Thorsten Oliver [1,2]; Solis-Escalante, Teodoro [1,2]

1: Zander Laboratories, Germany / The Netherlands;
2: Brandenburgische Technische Universität Cottbus-Senftenberg, Germany

Efficiently identifying specific targets within cluttered visual environments remains a challenge in various expert domains. We present a novel methodology employing 64-channel electroencephalography (EEG) and eye-tracking to investigate free visual search in complex visual scenes. Participants (N = 25) engaged in locating characters (e.g., Waldo and companions) within Where's Waldo images while EEG and eye movement data were synchronously recorded.

Fixation-related potentials were extracted from EEG data using eye-tracking information. Independent Component Analysis (ICA) aided in discerning neural signals from artifacts and revealed distinctive electrocortical patterns in the parietal cortex associated with target detection. These patterns showed a slow negative deflection specific to target identification, that was absent during fixations to non-target elements.

To test whether these patterns can be detected in single trials, we used classification approaches, including windowed means and regularized LDA. Eye movements in all classification approaches were removed using ICA. This approach achieved a mean cross-validation accuracy of 76% (SD ± 7%), surpassing the chance level of 56%.

Our approach was validated for online classification performance. By dividing EEG data into training and test sets, our approach upheld its better-than-random accuracy in identifying targets within cluttered visual scenes.

Our study reveals neurophysiological markers associated with target detection in complex visual scenes. Our findings offer insights into cognitive processes underlying visual search tasks and propose promising avenues for real-time applications. This could enhance future developments in neuroscientific research and improve computer vision algorithms through implicit expert input.

Key words: EEG, Eyetracking, Visual search, Target detection, Fixation-related potentials, Single-trial analysis

Walking through doors - Human brain dynamics of affordance processing based on intrinsically defined door heights

Wang, Sheng [1]; Djebbara, Zakaria [1,2];
Sanches de Oliveira, Guilherme [1]; Gramann, Klaus [1]

1: Biological Psychology and Neuroergonomics, Technische Universität Berlin, Berlin, Germany;
2: Department of Architecture, Design and Media Technology, Aalborg University, Aalborg, Denmark

Background. Affordances, the opportunities for action offered by the environment (Gibson, 1979), play a crucial role in guiding an agent's behavior. There is a debate in the field about whether affordances perception is an automatic response or not. Focusing on architectural affordances, we previously showed that cortical dynamics covary with perceiving and transitioning differently wide doors (Djebbara et al., 2019) according to different sensorimotor stages (Wang, Djebbara, Sanches de Oliveira, & Gramann, 2023). These results indicate that affordance perception is flexible and time-varying. However, all of the previously-mentioned research defined affordances in an extrinsic manner, i.e. the size of the door, neglecting the relational nature of affordances, i.e., the size of the door per size of the individual body (Gibson, 1979).
Method. Here, inspired by a methodology called intrinsic measurement (Warren, 1984), we adapted the task of Djebbara et al. (2019) by defining transitional affordances as the body-door height ratios. In addition, we introduced participants' body height as a between-subject factor. Focussing on early visual evoked potentials and late motor-related potentials, we investigate whether body heights modulate brain dynamics of affordance perception and whether time matters in the modulation.
Expected outcome. We hypothesize that ERPs reflecting affordance perception are not modulated by body heights in the early sensorimotor stage but are modulated in the later stages. Based on these findings from mobile EEG, we can examine the "intrinsic measurement" of affordances in sensorimotor brain dynamics, thus enriching the scientific understanding of flexible affordance perception in a relational and dynamical manner.

Key words: flexible affordance perception, Mobile Brain/Body Imaging (MoBI), sensorimotor time windows, intrinsic measurement, fit of body-door heights

CMI in older adults applying fNIRS to different walking conditions

Wollesen, Bettina; Drewes, Carolin; Asamoh, Janek

University of Hamburg, Germany

Daily situations often require to perform a walking and a cognitive task simultaneously (dual tasking, DT), e.g., crossing the street while observing traffic flow. With age, the DT ability decreases leading to cognitive-motor interference (CMI). This study investigates brain activity using a DT paradigm (visual discrimination task) while walking (barefoot or shoed).
Methods: 23 older adults (69.7 ± 5 years, females 74%) performed a 6-minute walking test in single- and DT conditions (responding to visual stimuli in the peripheral field). For both conditions, spatiotemporal gait parameters (speed, step length and double support time (DST)) using Opto-gait and prefrontal cortex (PFC) activity using fNIRS were measured. Statistical analysis was done with a one-way repeated measurement ANOVA (SPSS 29).
Results: There were no differences for gait parameters (Speed ST: 1.09 ± 0.18, DT: 1.07 ± 0.16; $F(1,18) = 1.026$; $p=0.325$; Step length: ST: 61.07 ± 8.09, DT: 60.58 ± 7.66; $F(1,18) = 1.121$; $p=0.304$; DST ST: 0.33 ± 0.05, DT: 0.34 ± 0.06; $F(1,18) = 1.129$; $p=0.302$). However, the barefooted and shoed ST condition differed for speed ($F(2,19) = 6.115$; $p=0.009$) and step length ($F(2,19) = 5.979$; $p=0.01$). fNIRS data will be presented at the conference.
Conclusion: Inconsistent to previous studies, the gait parameters did not show DT decrements. The observed difference in the walking condition (barefoot or shoed) did not remain under DT conditions. One potential explanation might be the task integration during the long-distance walk. We suggest that the CMI will be visibly in the fNIRS data of the PFC.

Key words: Dual-task walking, MoBI, older adults, functional Near-Infrared Spectroscopy

CMI in young, older, and older hearing-impaired adults investigating blink-related ERPs

Wunderlich, Anna [1]; Gramann, Klaus [1]; Wollesen, Bettina [2]

1: Technische Universität Berlin, Germany;
2: University of Hamburg, Germany

Age-related hearing decline increases the impact of cognitive motor interference in older adults. This results in impaired motor performance and an increased risk of falls. It remains unclear at which processing stage this interference is enhanced by hearing impairment.
To answer this question, the study compares 36 young and 36 older healthy participants to 36 older hearing-impaired participants using a mobile brain/body imaging (MoBI) approach in single and dual-task conditions. Participants performed a visual as well as an auditory stimulus discrimination task while seated or walking at their preferred speed. While stimulus-evoked potentials cannot compare both modalities and dual-task to single-task walking, the use of blink-related brain activity enables the comparison of dual-task costs across modalities and movement conditions.
During dual-task walking, the older hearing-impaired participants exhibit a stronger impact of cognitive-motor interference, as reflected by compensatory strategies such as longer double-support time and slower walking speed, as well as a higher number of omission errors, especially in the visual modality. Pending is the analysis of the task complexity modulation in the blink-related potentials (bERPs), which will be reported in the symposium. An exploratory analysis will compare the component amplitudes of the bERPs at frontal, central lateralized, and parietal electrodes to investigate contributions of central executive, motor-related, and information integration processes, respectively.
At the MoBI 2024 conference, the results of this extensive dataset, combined with the other talks from the symposium, will provide new insights into cognitive-motor interference and make a case for blink-related potentials in MoBI research.

Key words: Cognitive-motor interference, MoBI, blink-related potentials, hearing-impairment

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Understanding the Ear-Scalp Relationship Across a Battery of Cognitive Tasks

Adair, Devin Killion Petty; Nonte, Michael William; Hairston, William David

ARL, United States of America

Ear EEG is a promising approach for measuring cortical signals unobtrusively, making it a potentially powerful tool for a real-world mobile environment. However, we have yet to understand the relative amount of signal captured from the ear as compared to traditional scalp sites which is critical for connecting with prior work and predicting the usefulness of this technique for specific scenarios.
Here, we compare the fraction of explained variance (FVE) by in-ear and around-ear EEG acquisition as compared to the scalp for a series of typical seated lab tasks (RSVP, AEP, MEP, SSVEP, and ASSR). Common temporal and frequency domain features were defined for each task with the FVE computed from a regression between all electrodes for a given site and each individual scalp electrode based on the specified feature.
A smaller FVE was observed for all in-ear conditions compared with around ear, regardless of cognitive task, suggesting less general overlap in signal across features. However, the steady state tasks (ASSR and SSVEP) showed a higher FVE than single-item evoked potentials. Because those tasks have a lower overall SnR and require averaging over a high number of trials, we believe there is a direct link between the inherent signal power and the degree to which it is observable at the ear. Specifically, these results suggest that in-ear EEG is closest to the scalp data during strongly evoked potentials and in nearby scalp electrodes, while weaker sources may be difficult to parse.

Key words: EEG, cognitive task, FVE, inear EEG

Multimodal Fusion of EEG and Eye Blink Data in Cognitive Workload Detection

Alyan, Emad; Wascher, Edmund

Department of Ergonomics, Leibniz Research Centre for Working Environment and Human Factors, 44139 Dortmund, Germany

The advancement in cognitive neuroscience, augmented by the evolution of mobile EEG technologies, has significantly enhanced our understanding of covert cognitive processes in real-world settings. EEG has been recognized as a robust predictor of various aspects of human cognition and behavior. Yet, its efficacy can be further increased through the integration of multiple modalities. While the detection of cognitive workload using EEG has been extensively explored in the literature, this study posits that eye blinks, as captured by EEG channels, provide valuable complementary information. We introduce a novel cognitive workload detection methodology that synergizes EEG data with eye blink data. This approach employs a range of fusion techniques—namely, early, intermediate, and late fusion methods—and is evaluated across four distinct databases. Our empirical results explicitly demonstrate that these fusion methods improve classification accuracy across all datasets, surpassing the performance of methods employing only EEG. Notably, eye blink data alone exhibited lower classification accuracy compared to EEG data. However, the fusion of both modalities still resulted in higher classification accuracy. This study highlights the importance of integrating EEG and eye blink analysis in assessing cognitive workloads for complex tasks. It contributes significantly to the field by providing robust evidence of the effectiveness of fusion methods in task classification. This integrated approach not only enhances our understanding of cognitive workload but also suggests the potential for more sophisticated applications in cognitive neuroscience.

Key words: multimodal fusion, EEG, eye blink, workload, classification

Will you score? Motion capture of basketball shooting combined with mobile electroencephalography - on your smartphone

Contreras Altamirano, Miguel Angel [1]; Klapprott, Melanie [1]; Maanen, Paul [1,2]; Debener, Stefan [1,2]

1: Carl von Ossietzky University of Oldenburg, Oldenburg, Germany;
2: Cluster of Excellence "Hearing4All", Carl von Ossietzky Universität Oldenburg, Oldenburg, Germany

Developments in mobile electroencephalography (EEG) technology make it possible to record brain activity in everyday situations. To achieve good ecological validity, the recording setup should interfere as little as possible with natural behaviour. In addition, to better understand the relationship between brain activity and behaviour, it is necessary to combine EEG and motion tracking data. We developed a highly portable setup consisting of two tripods and two off-the-shelf Android smartphones. One smartphone was used to wirelessly collect 32-channel mobile EEG data along with video data. The second smartphone was used to capture behavioural patterns in real time by running an artificial intelligence motion capture application and streaming the derived body movement data, along with wireless motion sensor signals attached to the dominant hand, into a local area network. All data streams were time-synchronised using Lab Streaming Layer and stored on a smartphone. N=31 basketball players performed 120 basketball throws each. First, we investigated whether our setup allows to capture the readiness potential (RP) that precedes voluntary actions. Furthermore, we predicted that the RP would differ in morphology for successful versus unsuccessful shots. Preliminary data analysis confirmed that the RP can be captured for complex whole-body actions such as basketball shooting. We will present further results to assess whether EEG, motion capture data or both can predict shot success. In any case, a low-budget, small and lightweight acquisition setup consisting of only two smartphones is sufficient to reliably capture highly complex, natural brain-body relationships in natural settings.

Key words: Readiness Potential, Motion Analysis, Basketball, Artificial Intelligence, Motor Performance Prediction

A Comprehensive Study of Motion Artifacts in Ear-EEG

Dang, Thomas [1]; Nonte, Mike [1]; Adair, Devin [2]; Yu, Alfred [2]; Hairston, W.D [2]

1: DCS Corp, United States of America;
2: DEVCOM Army Research Laboratory, United States of America

As Mobile Brain/Body Imaging research moves into more realistic environments, there is a growing need for biosensors that allow participants to engage in natural behavior unencumbered by bulky equipment. Ear EEG, an emerging alternative to traditional scalp EEG, offers reduced setup time and allows subjects to engage in regular daily activity with minimal hindrance. To determine if Ear EEG recordings are usable for mobile research, the signal quality must be evaluated under a range of different behaviors. This work aims to evaluate Ear EEG data quality under a range of stereotyped and natural movements to determine its utility in everyday life.
Participants wore Ear EEG devices and VIVE Pro Eye head-mounted displays (HMD) which guided them through a series of 9 different natural and stereotyped motions including overground walking, isolated head movement, jaw movement, and rapid transitions between standing and prone.
Motion artifact severity was measured as the amplitude of the signal (VRMS) averaged over two-second windows. Transitions between standing and prone or crawling showed significantly larger artifacts than other motions ($p < 0.05$). Natural jaw movement during speech showed larger artifacts compared to rapid head rotation ($p < 0.05$). Self-paced overground walking during a search task showed larger artifacts compared to paced overground walking ($p < 0.05$). While Ear EEG was sufficient under several types of movement, we identified areas for future improvement in Ear EEG data quality to make it ready for the real world.

Key words: Ear EEG, Virtual Reality, Natural Movement, Motion Artifact

Decoding real-world visual scenes with LCD flicker glasses

Dowsett, James [1]; Martín, Inés [2]; Taylor, Paul [3]

1: University of Stirling, United Kingdom;
2: Technical University of Munich, Germany;
3: Ludwig Maximilians Universität München, Germany

In our research we are pioneering a method for decoding the visual scene from the evoked response in the EEG, using LCD glasses to add a flicker to the visual input of a participant. These glasses can be driven at any frequency, which we can match to the frequency of the brain's natural endogenous oscillations (alpha, gamma etc.). This has a number of useful applications for mobile and real-world EEG as we can add a visual flicker to whatever the participant is looking at: e.g. real-world scenes or other people during social interaction. In previous work we have demonstrated that the resulting evoked response (SSVEP), and cortical connectivity, varies as a function of the difference in frequency between the flicker and the participant's individual alpha frequency, indicating an interaction between the naturally occurring neural oscillations and the SSVEP. The complex waveform shapes evoked from visual flicker in the alpha band are unique to the visual scene the participant is looking at, most likely due to a unique combination of cortical sources. These differences are stable across testing days, and we are able to accurately decode what the participant is looking at from analysis of the waveform shape with as little as 5 seconds of data, from single electrodes. In a follow up study, we are testing the frequency specificity of this effect by comparing the decoding accuracy in the alpha band to other frequency bands, to demonstrate the role of specific frequency bands in the neural representation of the environment.

Key words: EEG, SSVEP, visual perception, neural oscillations

Mobile EEG in clinical practice: the undiscovered country

Dreo, Jurij; Jug, Jan; Aljaž, Barbara; Pavlovčič, Tisa; Ogrin, Ajda; Demšar, Anita; Agatić, Filip

BrainTrip, Malta

Despite major advancements in neuroscience and brain scanning, the most common diseases of the brain (depression, dementia, anxiety, migraine, parkinson's, schizophrenia...), representing 92% of all cases, still lack objective tests that are 1) confirmatory, 2) useful for early detection, and 3) widely clinically available. What clinicians do for every other organ: quick, simple, non-invasive, and objective assessment at the point-of-care, is still out of reach for the vast majority of brain diseases.
EEG is perfectly positioned to radically transform this landscape. It is by far the most affordable and least invasive approach for quantifying brain function. However, traditional clinical EEG has very limited applicability to just a few rare diseases (epilepsy) due to the inherent limitations of subjective EEG reading. Secondly, traditional clinical EEG hardware is cumbersome, overly specialized, and requires years of training for effective use.
We've developed cloud-based software that solves the problem of EEG's limited reach by: 1) Offering machine-assisted EEG recording that ensures collection of high-quality data with only 5h of training; 2) Performing fully automatic EEG processing requiring no expertise; 3) Quantifying brain function with hundreds of redundant EEG biomarkers corrected for common confounders (age, sex, education level...) and synthesized with machine learning. This makes EEG scalable and applicable to most brain diseases. Our software permits a mobile EEG to perform point-of-care detection of early signs of dementia with high accuracy (95% specificity, 80% sensitivity).
This result should encourage hardware companies specializing in mobile EEG to vigorously pursue not just research, but also clinical applications.

Key words: clinical practice, point-of-care, EEG, neurological disorders, diagnostics

Chewing restores frontal theta oscillation after somatosensory disruption and modulates the connectivity of the working memory-related network

Espinoza, Sebastian [1,2]; Cáceres, Samuel [2]; Salinas, Manuel [2]; Moraga, Daniel [3,4]; Monrreal-Ortega, Luis [3]; El-Deredy, Wael [1,5,6]

1: Brain Dynamics Laboratory. Universidad de Valparaíso, Chile;
2: School of Dentistry, Universidad de Valparaíso, Chile;
3: Chemistry and Pharmacy school, Pharmacy faculty, Universidad de Valparaíso, Chile.;
4: Chilean FARMACOPEA research center Universidad de Valparaíso, Chile.;
5: ValgrAI: Valencian Graduate School and Research Network of Artificial Intelligence.;
6: Department of Electronic Engineering, School of Engineering, Universitat de València, Spain.

We simulate tooth loss using local anesthesia to test how altered oral somatosensory afference modulates brain oscillations, specifically EEG theta oscillations and working memory (WM) performance.
Twenty-six healthy right-handed volunteers (24-60 years old) were recruited with no recent mental health diagnosis or treatment (less than one year), no temporomandibular disorders according to the DC-TMD screening test, and had all-natural teeth.
Participants performed a WM task comprising the visual two-back test (2B) under a 2x2 factorial design: Chewing (previous to task chewing yes/no) and dental anesthesia (yes/no). We also tested brain connectivity through a dynamical causal model for EEG data-induced responses (DCM-Ind). We tested the ROIs based on the previous works of (Hirano et al., 2013), which we simplified in three nodes: left superior temporal gyrus (L.STG; -53.16, -20.68, 7.13), left supplementary motor area (L.SMA; -5.32, 4.85, 61.38), and right postcentral gyrus (R.POCG; 41.43, -25.49, 52.55)
Chewing increases working memory performance after somatosensory disruption of the oral cavity. Dental anesthesia decreased the theta frequency power in the induced activity and was restored after chewing. This increase could be related to compensation for the cognitive effort that implies somatosensory disruption. The chew frequency is increased under dental anesthesia, which explains a dependency on the theta activity and chewing.
The modulatory effect of anesthesia could act at the POCG and STG levels, which controls this difference. In our context, anesthesia decreases theta activity, decreasing behavioral performance.

Key words: Working memory, Chewing, DCM, Time-frequency, Tooth loss

The Influence of adding cognitive tasks with a balance board on Dorsal Attention Network Connectivity at the Source Level

Ghani, Usman [1]; Niazi, Imran Khan [1,2,3]; Signal, Nada [2]; Kumari, Nitika [1]; Amjad, Imran [1]; Haavik, Heidi [1]; Taylor, Denise [2]

1: Centre for Chiropractic Research, New Zealand College of Chiropractic, Auckland, New Zealand;
2: Department of health and sciences, Auckland University of Technology (AUT), New Zealand;
3: Department of Health Science and Technology, Aalborg University, Aalborg, Denmark

This study investigates how adding a cognitive task on a balance board (exergame) affects connectivity in the dorsal attention network (DAN). Healthy young adults performed a soccer ball-moving task by tilting a balance board with their feet while their brain activity was measured using electroencephalography (EEG). In this exergame, the speed of obstacles in front of the goal manipulated the cognitive task difficulty. Higher speed means a higher difficulty. The study found significant changes in functional connectivity within DAN regions, specifically in the alpha band. During the shift from easy to medium cognitive task, we observed a significant increase in connectivity ($p = 0.0436$) between the right inferior temporal (ITG R) and the Left middle temporal (MTG L). During the transition from easy to hard cognitive tasks, strengthened interactions ($p = 0.0324$) between inferior temporal (ITG) and parsopercularis (pOPPER) were found. This suggests that the proposed balance board-based exergame enhances the functionality of specific brain regions, such as ITG and MTG regions, and improves connectivity in the prefrontal cortex. These findings align with the research that suggests that adding games to physical activity-based tasks in rehabilitation programs can boost brain activity, resulting in improved decision-making and visual processing skills. This information can be helpful for clinicians to tailor rehabilitation methods that target specific brain regions.

Key words: Dorsal Attention Network (DAN); Cognitive; Electroencephalogram (EEG), Exergame, and Phase lag index (PLI)

Measuring the effect of nGVS on brain connectivity during a dynamic environment: An EEG study

Ghani, Usman [1]; Niazi, Imran Khan [1,3]; Mclaren, Ruth [2]; Taylor, Denise [2]

1: Centre for Chiropractic Research, New Zealand College of Chiropractic, Auckland, New Zealand;
2: Department of health and sciences, Auckland University of Technology (AUT), New Zealand;
3: Department of Health Science and Technology, Aalborg University, Aalborg, Denmark

This study investigated whether noisy galvanic vestibular stimulation (nGVS) could improve postural control and demonstrate the feasibility of measuring brain activity alongside nGVS during static and dynamic tasks. We collected 16-channel EEG data using a mobile EEG and nGVS system from a single participant who performed various tasks, including standing and tandem standing with eyes open and closed, gait with eyes open and closed, and gait in an imaginary line with eyes open and closed. During the static tasks, the participant stood for three minutes, with 30 seconds of nGVS on and 30 seconds off. For the gait task, eight trials were recorded, with four using nGVS and four without. EEG data was continuously recorded with triggers marking nGVS on and off. We used Phase Lag Value (PLV) to measure changes in sensor-based connectivity within tasks to observe the effect of nGVS. Our analysis found that the EEG connectivity between prefrontal (FP1, FP2) and parietal (P3, P4) regions increased with nGVS during both static and dynamic tasks. These findings suggest that nGVS effectively enhances brain connectivity to improve balance and demonstrate the feasibility of using EEG in dynamic tasks like balance and gait. The findings also pave the way for future research investigating the relationship between neurophysiological measures and balance-related data, providing deeper insights into the efficacy of nGVS in enhancing postural control.

Key words: nGVS, Electroencephalogram (EEG), Gait, Balance, Connectivity, Phase Lag Value (PLV)

Mobile Brain/Body Imaging of three-ball juggling: Dynamics of neurobehavioral interactions between motor execution and perception

Iversen, John Rehner [1,2]; Kim, Hyeonseok [2]; Miyakoshi, Makoto [3]; Kambara, Hiroyuki [4]; Tanaka, Hirokazu [5]; Takahiro, Kagawa [6]; Cho, Wanhee [7]; Makeig, Scott [2]; Yoshimura, Natsue [7]

1: McMaster University, Canada;
2: University of California San Diego, USA;
3: Cincinnati Children's Hospital Medical Center, USA;
4: Tokyo Polytechnic University, Japan;
5: Tokyo City University, Japan;
6: Aichi Institute of Technoloty, Japan;
7: Tokyo Institute of Technology, Japan

This project developed three-ball juggling as a neurobehavioral model of complex skill learning. Using new approaches to jointly analyze movement and brain activity, we present results from the MoBI analyses of thirteen jugglers of varying skill studied at normal gravity and behavioral showing that juggling training under simulated reduced gravity can enhance skill acquisition. Brain dynamics were assessed using spectro-temporal analysis of cortically resolved high-density scalp EEG referenced to timing events extracted from motion capture data. Using new methods for movement artifact rejection, it is possible to reliably extract spatially localized brain activity related to visual processing, spatial attention, multi-sensory integration and motor execution. In the parietal cortex, known to be involved in spatial processing, alpha-band robustly desynchronizes at the moment the thrown ball reaches its apex, a time thought to be critical for trajectory estimation required for the planning of the timing and location of the next catch. Accordingly, parietal activity demonstrates a clear biomarker of the trial-to-trial deviation of the ball's apex position in a natural center-out body-centered coordinate frame. A notable finding is an unusually narrow-band activity between 70-80 Hz that shows periodic modulation with positive/negative peaks corresponding to contralateral/ipsilateral throws and sharp transitions corresponding to catches, suggesting a possible role in intra-hand coordination. Three-ball juggling is a promising example of a complex skill learning that can be studied with MoBI to provide insights into the dynamics of neurobehavioral interactions between motor execution and perception.

Key words: skill, parietal, EEG, learning, mocap

Exploring the Mobile EEG Multiverse

Jacobsen, Nadine Svenja Josée; Kristanto, Daniel; Debener, Stefan

University of Oldenburg, Germany

Preprocessing of electroencephalography (EEG) data is crucial for obtaining meaningful and interpretable results. While various preprocessing approaches are justifiable, their impact on outcomes may be significant. The impact of preprocessing decisions has been studied in stationary EEG but remains unexplored in mobile EEG. This study explores the uncharted territory of preprocessing decisions in mobile EEG, where complex processing is necessary to address motion artifacts. Specifically, we will investigate the influence of preprocessing choices on the amplitude of the P3 event-related potential (ERP) during walking and standing to understand the robustness of different processing options.

Using a systematic literature review, 27 of the initially screened 258 studies on P3 during standing and walking using mobile EEG met the inclusion criteria. Extraction of preprocessing choices revealed commonalities and differences between studies. Offline filters were ubiquitous, whereas line noise correction was rarely applied (3 of 27 studies). In addition, 63% of the studies included at least one manual processing step, and 52% did not report critical parameters of at least one processing step.

Our results are consistent with those obtained for stationary EEG preprocessing and underscore the need for standardized reporting in mobile EEG. To facilitate the exploration of the preprocessing landscape, we present a Shiny app that allows users to compare their preferred processing to the literature and expert recommendations. With this approach, we hope to raise awareness about the potential impact of preprocessing decisions and advocate for comprehensive reporting standards to enhance result reproducibility in mobile EEG research.

Key words: Mobile EEG, preprocessing, literature review, P3, gait

Accurate prediction of gait events using EEG motion artifacts

Kankar, Rushikesh Harikishan; Huang, Helen J.

University of Central Florida, United States of America

Electroencephalography (EEG) motion artifacts are readily recorded during mobile brain/body imaging (MOBI) activities. As such, we have been exploring the potential of extracting useful information for interpreting MOBI tasks based on EEG motion artifacts. The purpose of this study was to investigate predicting gait events (left and right heel strikes and toe-offs) using EEG and machine learning. We hypothesized that EEG motion artifacts would provide the highest accuracy for predicting gait events if they are indeed generated by gait movement dynamics. We analyzed dual-layer EEG data, which provides traditional scalp EEG signals and coupled isolated electrical noise and motion artifact signals, from a prior lab perturbed walking study. We trained random forest, logistic regression, and support vector machine models with datasets of EEG motion artifacts only, minimally cleaned EEG, cleaned EEG, and source signals from independent component analysis to predict heel strikes and toe-offs. We also explored the number of input signals, epoch lengths, and different time series features using the Time Series Feature Extraction Library (TSFEL) Python package. So far, the EEG motion artifact only dataset produced the highest accuracy (~75%-90%), regardless of the machine learning model, number of input signals, epoch length, and features used. For the remaining datasets, the accuracy performance for minimally cleaned EEG that retained motion artifact contributions had the next highest accuracy, followed by source signals (i.e. independent components). The cleaned EEG had the lowest accuracies (~35%-45%). These results suggest that EEG motion artifacts contain useful information for predicting gait events.

Key words: artifact, machine learning, prediction, gait, motion

Lessons learned in an extensive journey through multifaceted analyses of a MoBI situational awareness experiment in VR

Klug, Marius [1]; Rabe, Lea [1]; Pan, Yanzhao [1]; Gramann, Klaus [2]

1: BTU Cottbus-Senftenberg, Germany;
2: TU Berlin, Germany

Situation awareness (SA) is a critical cognitive process in dynamic environments that involves the perception, comprehension, and projection of environmental elements. Previous studies have primarily used behavioral measures to assess SA, with limited exploration of its neural correlates using electroencephalography (EEG). This study extends previous research by employing a Mobile Brain/Body Imaging (MoBI) paradigm in a virtual reality (VR) environment, where participants interacted with target and distractor spheres, to uncover neural markers of SA. Task difficulty was modulated by stimulus discriminability, predictability, and color visibility. We collected high-density EEG, motion capture, eye tracking, performance, and subjective measures of SA and workload. We performed EEG analysis using event-related potentials (ERPs) and spectral measures. Behavioral data revealed performance variations across difficulty levels, which were successfully modeled using gaze and motion measures. Fixation-based ERPs were able to distinguish between different levels of discriminability, visibility, and predictability. However, attempts to quantify mental workload using spectral analysis or a classifier calibration paradigm, as well as continuous performance prediction based on EEG 1/f component analysis, were unsuccessful. The findings provide mixed outcomes in the search for EEG correlates of SA in a dynamic VR environment, and the study highlights the complexities and challenges of neurophysiological research on SA in interactive VR settings, which we look forward to discussing.

Key words: situation awareness, null results, eye gaze, EEG

Impact Study of Meditation on Brain and Stress Using EEG Signals

Lotia, Siddharth; Banshpal, Ishan

IIIT Bangalore, India

This work explores the dynamic interplay between meditation, stress reduction, and electroencephalography (EEG)-based measurements. Our primary aim is to discern and characterize the impact of meditation on brain activity and its potential role in stress reduction. Leveraging EEG data from both meditators and non-meditators during meditation and rest states, we employ signal processing techniques and a machine learning-based classifier for differentiation. Subsequently we dive deeper into various bands of EEG signals, our study focuses on the comparative analysis of alpha, beta, and theta power values as key features extracted from EEG signals.

Our findings aim to illuminate specific neural patterns associated with meditation, addressing whether meditation induces a shift from stress-related beta power activity to a non-stress state and potentially enhances relaxation through increased alpha and theta power activities. We explore both time domain and frequency domain features. By investigating these EEG-derived features, we contribute to a nuanced understanding of the physiological mechanisms underlying meditation-induced stress reduction.

Key words: Machine Learning, Meditation, Electroencephalography, Signal Processing

Test-retest reliability of perturbation evoked potentials reveals individual differences in reactive balance control

Mirdamadi, Jasmine L; Jones, Kendra; Munter, Gaetan; Poorman, Alexander; Ting, Lena H; Borich, Michael R.

Emory University, United States of America

There is growing interest in measuring brain activity during balance control for understanding mechanisms of balance-related impairments and falls in aging and neurological dysfunction. A sudden loss of balance elicits a well-characterized perturbation-evoked potential that is associated with individual differences in balance function in younger and older adults, suggesting it may be a valuable electrophysiological biomarker of balance health. However, the reliability of the N1 has yet to be established, a necessary step towards advancing its clinical utility as a prognostic or monitoring tool for fall risk. Here, we examined the test-retest reliability of the N1 evoked by standing balance perturbations in younger and older adults. Participants completed two sessions separated within one week. 64-channel electroencephalography (EEG) was recorded while participants discriminated the direction of whole-body motion elicited by pairs of support-surface translations. We extracted N1 amplitude and latency from the Cz electrode, defined as the first and largest negative potential 100-250 msec post-perturbation. Reliability was assessed with the intraclass correlation coefficient (ICC). N1 characteristics varied across individuals (amplitude: 8 μV – 70 μV, latency: 130 ms – 190 ms), yet within individuals, showed strong test-retest reliability (amplitude: r = 0.97; latency: r = 0.90). In older adults, N1s were slower and smaller, but preliminary data indicate similar test-retest reliability as younger adults. Findings suggest that the N1 is stable across sessions and may be a useful electrophysiological biomarker for understanding mechanisms of balance-related impairments and responses to treatments.

Key words: EEG, reactive balance, perception, aging, reliability

Unsupervised learning of brain network dynamics associated with adaptation to exoskeleton assistance during walking

Naeem, Jasim [1]; Song, Seongmi [2]; Bradford, J. Cortney [3]

1: DCS Corp;
2: Texas A&M University;
3: US DEVCOM Army Research Laboratory

We aim to better understand the changes in neural activity associated with adaptation to exoskeleton assistance during walking. The goal of this study was to determine whether cortical network activation changes as a user becomes accustomed to walking with exoskeleton assistance. 22 subjects walked on a treadmill while wearing a powered bilateral ankle exoskeleton that assisted with plantarflexion at toe off. We measured 128 channel electrocorticography (EEG) while participants practiced walking with exoskeleton assistance for 1 hour. EEG data were submitted to a 2-model Adaptive Mixture Independent Component Analysis (AMICA) to observe how and when cortical brain networks changed across the 1 hour of walking. In 19 of 22 subjects, the model probability time-series revealed two distinct models primarily representing early and late adaptation periods during walking with the exoskeleton. The average model transition time occurred at 39.5% (SD=9.1%) of the total walking time. All but one subject showed change between the two models in identified neural components as determined by Euclidean distance between dipole locations (>10mm), Brodmann area label, and magnitude-squared coherence (<0.5 in alpha and beta band frequencies). In a prior study, we observed a significant change in walking biomechanics over time, suggesting that study participants were able to better cooperate with the exoskeleton after practice. Together, the data suggest that most of the study participants experienced a shift in cortical brain network activations as they learned to cooperate with exoskeleton assistance during walking.

Key words: exoskeleton, EEG, AMICA

Investigating EEG signatures of face perception during free-viewing in a naturalistic virtual environment.

Nolte, Debora [1]; Madrid-Carvajal, John [1]; Koenig, Peter [1,2]

1: Institute of Cognitive Science, University of Osnabrück, Osnabrück, Germany;
2: Department of Neurophysiology and Pathophysiology, University Medical Center Hamburg-Eppendorf, Hamburg, Germany

Faces are considered prevalent and important stimuli (e.g., Wheatley et al., 2011) and their EEG signatures are well documented and understood. However, common investigations use standardized lab settings with high experimental control, during which eye movements are generally restricted, and the fixated stimuli are predetermined. Little research has explored the perception of faces in controlled yet naturalistic settings. The current study combines high experimental control with natural viewing and movement behavior by investigating face perception in a virtual environment. Our virtual city consists of houses, various background stimuli, and, notably, static and moving pedestrians. Participants freely explore the virtual scene while eye-tracking and EEG data are recorded. We investigated participants' EEG signatures when fixating on different stimuli, separated into faces, bodies, and background stimuli. Preliminary results indicate negative N170 components for faces, followed by less negative N170 results for bodies and the least negative components for background stimuli. Employing a temporal decoding allowed us to differentiate between the three conditions. These findings show a graded difference of processing the face vs. body vs. background in a naturalistic virtual environment and help to establish VR as a suitable research method for these questions.

Wheatley, T., Weinberg, A., Looser, C., Moran, T., & Hajcak, G. (2011). Mind perception: Real but not artificial faces sustain neural activity beyond the N170/VPP. PloS one, 6(3), e17960.

Key words: face perception, N170, virtual reality, natural viewing, fixation-onset ERPs

Multiscale Entropy Analysis in Mobile Eeg: Could It Have a Potential Use in Real-World Settings?

Piskin, Daghan; Cobani, Gjergji; Lehmann, Tim; Büchel, Daniel; Baumeister, Jochen

Paderborn University, Germany

The complexity of brain is representative of its information capacity with distinctive characteristics in specific cognitive states and pathological conditions. Multiscale Entropy (ME) is one measure to analyze the complexity of electroencephalography (EEG) signal with its strongest merit to regard slow and fast dynamics at multiple time scales. It is capable of profiling cohort-, disorder- and state-specific characteristics in resting EEG, however, no studies have considered ME analysis in a mobile setting so far. It may provide substantial insights to understand movement-related brain complexity in an ecologically valid frame. Therefore, the aim of this study was i) to assess test-retest reliability of ME in EEG signal recorded during a sport-specific task, ii) to explore if ME is able to detect differences in task-related complexity of cortical activity between novices and experts. For our first aim, we computed channel- and scale-wise intraclass correlation coefficients for ME in 64-channel preprocessed EEG signals, which was recorded twice within a week in 11 novices. For our second aim, we compared entropy values for 64 channels and scales between 15 novices and 15 experienced players using independent t-tests. Our findings showed overall acceptable reliability for ME values computed in preprocessed EEG signal. There were significant group differences characterized by channel- and scale-specificity indicating expertise-specific modifications in the complexity of task-relevant activity. Our findings may propose the potential use of ME analysis in real-world EEG settings, which may prospectively help to comprehend the impact of complex neural dynamics on human movement at diverse contexts.

Key words: eeg, multiscale entropy, brain complexity, mobile eeg, movement

An acute exercise intervention to ameliorate behavioral and neurophysiological indices of inhibitory control deficits in schizophrenia: A Mobile Brain/Body Imaging (MoBI) study

Popov, Victoria A.; Freedman, Edward G.; Foxe, John J.

The Frederick J. and Marion A. Schindler Cognitive Neurophysiology Laboratory, Department of Neuroscience, The Del Monte Institute for Neuroscience, University of Rochester School of Medicine and Dentistry, United States of America

Background: Inhibitory control deficits are a core feature of schizophrenia spectrum disorders (SSDs), with clear manifestations seen in psychophysiological and electrophysiological measures of these processes. An intriguing set of findings has suggested exercise can have a positive effect on SSD symptomatology, but the exercise-linked neural changes that may result in improved inhibitory control are unknown.
Methods: Participants with SSDs and controls completed the Go/NoGo response inhibition (RI) task while sitting or engaged in treadmill walking. We leverage MoBI technologies to ask whether a single acute treadmill walking exercise intervention would lead to improved performance on a canonical RI task, and if well-characterized deficits in the generation of inhibition-related event-related-potential (ERP) components can be ameliorated in SSDs.
Results: Simple main effects analysis showed that groups had a statistically significant effect on d’ scores ($F(1, 29) = 11.30$, $p = .001$) and motion state did not ($F(1, 29) = 0.20$, $p = .65$). The cluster-based permutation approach showed significant ERP amplitude increases during walking over frontal and frontocentral scalp regions and reductions over parietal and occipital scalp regions during RI related ERP component intervals for controls and SSDs, and earlier in controls.
Discussion: Findings suggest a single intervention of treadmill walking showed no improvement in inhibitory control performance but normalization of neurophysiological processes in SSDs to those of controls. We expect when we are sufficiently powered SSDs will show inhibitory control performance like those of controls when walking. A longer-term fitness intervention trial could assess whether these positive outcomes can be established more durably.

Key words: schizophrenia, response inhibition

Low-Gamma Band Reveals Different Effective Connectivity Patterns between Healthy Controls and MCI Patients during a Motion Detection Task

Renli, Alina B. [1,2]; Gu, Ming [2]; Sun, Boxin [2]; Li, Tongtong [2,6]; Kavcic, Voyko [3,4]; Giordani, Bruno [5,6]

1: Department of Neuroscience, Michigan State University, East Lansing, MI, USA;
2: Department of Electrical and Computer Engineering, Michigan State University, East Lansing, MI, USA;
3: Institute of Gerontology, Wayne State University, Detroit, MI, USA;
4: International Institute of Applied Gerontology, Ljubljana, Slovenia;
5: Departments of Psychiatry, University of Michigan, Ann Arbor, MI, USA;
6: Michigan Alzheimer's Disease Research Center, Ann Arbor, MI, USA

Background: Effective connectivity, which represents the directed connectivity or information flow from one brain region to the other, has been proposed to identify people at risk for mild cognitive impairment (MCI). The present study investigates how cognitive engagement changes the effective connectivity in the brain.
Method: Our research focuses on task-based EEG (64-channel), where participants with subjective cognitive complaints were asked to perform a motion direction discrimination task. The current dataset includes 56 consensus-diagnosed, community-dwelling African Americans (ages 60-90 years, 28 healthy controls (HC) and 28 MCI patients) recruited through the Wayne State Institute of Gerontology and Michigan Alzheimer's Disease Research Center.
We evaluated the effective connectivity at different time periods of the motion-detection task across all the possible EEG region pairs using causalized convergent cross-mapping (cCCM) of the current source density. For each task trial, the successive time periods being examined included: (I) stimulus onset to Go/NoGo indication, (II) Go (or NoGo) indication to motion-stop, and (III) the button-press period.
Results: Our analysis indicated that in all the time periods during the motion task, MCI shows increased effective connectivity in low-gamma band (30-48Hz) over MP(medial parietal)Û OCC(occipital) and MPÛMC (Medial central) pairs.
Conclusion: Our results add to the existing findings that Gamma waves are correlated with visual consciousness, attention and working memory, and altered gamma activity is often observed in patients with cognitive impairment. Our analysis provides new features for future biomarker development for effective discrimination of HC and MCI.

Funding: NSF-2032709/Li; NIH-1R21AG046637-01A1/Kavcic and NIH-1R01AG054484-01A1/

Kavcic; NIH-P30AG072931/Paulson NIH-P30AG024824/Yung.

Key words: Mild cognitive impairment, effective connectivity, gamma band, motion task

Older Adults' Brain Activations Vary with Treadmill Walking Speed and Surface Unevenness

Salminen, Jacob (1); Liu, Chang (1); Pliner, Erika M. (2); Richer, Natalie (3); Hwang, Jungyun (4); Clark, David J. (4,5); Seidler, Rachel (6,7,8); Hass, Chris F. (6); Manini, Todd M. (9); Cruz-Almeida, Yenisel (10,11,12); Ferris, Daniel P. (1,8)

1: Department of Biomedical Engineering, University of Florida, Gainesville, FL, USA;
2: Department of Mechanical Engineering, University of Utah, Salt Lake City, UT, USA;
3: Department of Kinesiology and Applied Health, University of Winnipeg, Winnipeg, Canada;
4: Department of Neurology, University of Florida, Gainesville, FL, USA;
5: Brain Rehabilitation Research Center, Malcom Randall VA Medical Center, Gainesville, FL, USA;
6: Department of Applied Physiology and Kinesiology, University of Florida, Gainesville, FL, USA;
7: Norman Fixel Institute for Neurological Diseases, University of Florida, Gainesville, FL, USA;
8: McKnight Brain Institute, University of Florida, Gainesville, FL, USA;
9: Department of Health Outcomes and Biomedical Informatics, University of Florida, Gainesville, FL, USA;
10: Department of Community Dentistry and Behavioral Science, University of Florida, Gainesville, FL, USA;
11: Pain Research and Intervention Center of Excellence, University of Florida, Gainesville, FL, USA;
12: Department of Epidemiology, University of Florida, Gainesville, FL, USA

Aging decreases mobility and gait stability in humans. Sarcopenia, reduced metabolic capacity, and neuron death due to inactivity all correlate with frailty, but these physical factors don't fully explain observed incidences falls in older adults [1,2]. We recorded high-density EEG of older adults (n=55, 65-90y/o, 28f) walking at different speeds and terrain difficulty levels to understand cortical contributions to gait stability. We used a sacral IMU and foot force sensors to determine gait events. We localized electrocortical activity using custom finite element conductivity head models sourced from each subject's anatomical MRI [3,4]. A k-means clustering (k=12) of our sample found common brain regions around sensorimotor, posterior parietal, cuneus, and anterior cingulate. A linear mixed effects model determined the effect of terrain difficulty on mean power in theta, alpha and beta bands for each brain region. Significance level was set alpha < 0.05. As terrain difficulty increased, we observed decreases in left and right sensorimotor alpha (Left: $F(3,168)=16.6$, Right: $F(3,160)=11.8$) and beta band power ($F(3,168)=18.9$ and $F(3,160)=8.67$). Left and right posterior parietal decreased alpha ($F(3,120)=8.32$ and $F(3,156)=26.1$) and beta power ($F(3,120)=12.8$ and $F(3,156)=27.3$) on more difficult terrain. Conversely, left

posterior parietal's theta power increased ($F(3,120)=3.91$) with terrain difficulty. Mid-posterior cingulate decreased alpha ($F(3,124)=7.11$) and beta ($F(3,124)=16.2$) power with increasing terrain difficulty. Cuneus decreased beta power ($F(3,180)=23.0$) while simultaneously increasing theta power ($F(3,180)=10.9$) to the terrain challenge. Findings show a broad network of brain areas involved in navigating uneven terrain, where an increase in difficulty correlates with an increase in brain resources.

Key words: high-density EEG, clinical, aging, neuroscience

Modeling event durations and overlap in evoked responses

Skukies, René [1,2]; Schepers, Judith [2]; Ehinger, Benedikt [1,2]

1: SimTech - University of Stuttgart, Germany;
2: Institute for Visualisation and Interactive Systems - University of Stuttgart, Germany

Cognitive sciences are increasingly embracing quasi-experimental designs, particularly evident in mobile EEG studies where many aspects are not under the control of the experimenter. However, these designs pose a notable challenge: the control of confounding variables. One largely overlooked confound is the temporal duration of an event (e.g. an eye fixation, a reaction time, or the duration of a sound). When inspecting the distributions of such confounds, we often noticed they differ between conditions and participants. As it is reasonable to expect them to influence the ERPs (if calculated via classical averaging), we should be aware of a potential bias invalidating our conclusions. Even more alarming, varying durations usually co-occur with temporal overlap of consecutive events, adding further bias. While temporal overlap has recently been addressed using linear deconvolution, it remains unclear how best to model duration effects, and whether such duration-modelling can be disentangled from overlap effects.
Using simulated and real-world data, we systematically explore how duration and overlap affect the resulting ERPs and how to adequately capture both effects separately but also simultaneously using a regression-based statistical model within the unfold-toolbox framework (https://www.unfoldtoolbox.org/).
We found that simple binning as well as linear effect modelling of duration performs poorly in many scenarios. However, non-linear effects using spline-regression seem to be able to capture the main patterns and are thus a promising candidate for further study. Crucially, our simulations demonstrate the feasibility of integrating overlap correction and non-linear spline estimation within a unified model, despite their shared confounding influence.

Key words: EEG, overlap correction, regression modelling, deconvolution, rERP

Human electrical brain and muscle dynamics during underwater bodyweight supported locomotion

Song, Seongmi [1]**; Nordin, Andrew D.** [1,2,3]

1: Division of Kinesiology, Texas A&M University, College Station, TX, USA;
2: Department of Biomedical Engineering, Texas A&M University, College Station, TX, USA;
3: Texas A&M Institute for Neuroscience, Texas A&M University, College Station, TX, USA

Human locomotor control requires nervous system coordination that is affected by external loading conditions. Partial body weight support is commonly used during gait rehabilitation to reduce loads applied to the body and limit balance demands that may be compromised due to injury or impaired motor function. Underwater bodyweight support occurs due to the buoyancy of the human body that is offset by greater drag forces from the surrounding external fluid, underscoring a need to better understand how the human brain and muscles adapt to altered loading conditions during underwater gait. Our aim was to determine the influence of external loading conditions on human electrical brain and muscle activation dynamics during underwater treadmill locomotion. Ten participants walked on an underwater treadmill at 1.2 m/s, while we recorded mobile high-density electroencephalography and lower limb electromyography. To alter bodyweight support during underwater treadmill walking, we adjusted the water depth to waist and chest levels, increasing bodyweight unloading at greater underwater depth. During underwater treadmill walking, we identified interactive changes in electrical brain and muscle dynamics. Compared to walking underwater at waist-level, greater bodyweight support during chest-level underwater walking reduced electrical muscle activation amplitudes, but increased alpha band spectral power (8-13 Hz) from the frontal cortex and beta band spectral power (13-30 Hz) from the parietal cortex. Our results identify reduced cortical processing and muscle activity during bodyweight supported locomotion that may be used to tune rehabilitation protocols based on electrocortical and myoelectric biomarkers for detecting sensorimotor adaptations to external loading conditions.

Key words: Bodyweight support, Gait, Aqua walking, EEG, EMG

Real-life cortiical speech tracking and attention decoding

Straetmans-Oehme, Lisa [1]; Adiloglu, Kamil [2]; Debener, Stefan [1]

1: Carl-von-Ossietzky Universität Oldenburg, Germany;
2: Hörzentrum Oldenburg

Complex auditory situations are a nearly unavoidable component of everyday life settings. When we sit in a busy train or walk through a crowded city we are continuously confronted with a range of different sounds.Such situations tax a lot of our attentional resources. Non-invasive brain imaging technologies like Electroencephalography (EEG) could be used to assist the auditory system. Most studies in this area neglect an important aspect: laboratory findings often do not relate well to real life settings. Brain imaging technologies like EEG are highly susceptible to movements and the association between audio and EEG may be influenced by distractions introduced by less controlled environments. After we showed previously, that EEG-based auditory attention decoding is in fact possible while participants walk indoors (Straetmans et al., 2022), the current study aimed to capture even higher environmental complexity. Participants were instructed to attend to one out of two simultaneously presented speakers while walking along calm and busy streets or sitting in a quiet hallway. Our preliminary results show, that neural tracking of the attended speaker is reduced and only marginally above chance level when participants were walking outside. One factor that might explain the difference to our previous findings is that the environment of the second study was largely uncontrolled and stimuli might have temporally been inaudible. Additionally, data might be contaminated with a lot of movement artefacts. A next analysis step will be to employ a more thorough artefact attenuation strategy to investigate the influence of movement artefacts.

Key words: Auditory Attention Decoding, Neural speech tracking, mobile EEG, Beyond-the-lab

Serving and Hitting in Table Tennis as a Way to Understand Bimanual Coordination

Studnicki, Amanda [1]; Seidler, Rachael [2]; Ferris, Daniel [1]

1: J. Crayton Pruitt Family Department of Biomedical Engineering, University of Florida, United States of America;
2: The Department of Applied Physiology and Kinesiology, University of Florida, United States of America

The brain's functional lateralization requires effective coordination between hemispheres for visuomotor control of everyday activities. In this study, we used table tennis as an ecologically valid way to study hemispheric specialization. We focused on serve hits, a shot that requires bimanual coordination (i.e., tossing the ball with the left hand and hitting the ball with a paddle in the right hand). Contrasted with other types of hits (e.g., rally and return of serves), we hypothesized that serve hits would show a greater magnitude of spectral power fluctuations in the right sensorimotor cortex to reflect control of the left-handed toss. We also hypothesized that interhemispheric connectivity would be higher during a serve since bimanual maneuvers typically show more bilateral brain activity than unilateral maneuvers.
Right-handed participants (n=37) played table tennis while we recorded dual-layer EEG, accelerometer data for timing of hit events, and video. After pre-processing the data, we used Independent Component Analysis and subject-specific head models to model dipolar, source-localized component activity. Time-frequency analysis, event-related potentials, and functional connectivity metrics were our main outcome measures.
The right sensorimotor cortex showed a greater magnitude of spectral power fluctuations for serve hits than return or rally hits. Surprisingly, we found little difference in connectivity between hemispheres for different hit types, even though a serve could arguably be more complex. Our work contributes to the understanding of hemispheric specialization in a more natural environment, which could provide valuable insight for sport training and rehabilitation.

Key words: EEG, table tennis, hemispheric specialization

Walking and seeing – about the interaction of walking and visual information processing

Lieker, Emma Louise Dorothea; Reiser, Julian Elias; Rinkenauer, Gerhard; Wascher, Edmund

Leibnitz Research Centre for Working Environment and Human Factors (IfADo)), Germany

Poster: collected data

Background: Concurrent locomotion and visual processing are a set of tasks we are facing every day. Though walking is a rather automatic process, some properties of the walking path can increase cognitive demands necessary for locomotion, making it a naturally occurring cognitive-motor dual-task. Investigating the link between gait and visual processing in natural environments is thus crucial for mobility and fall prevention.

Methods: This experiment will involve 36 healthy participants (aged 18-30, 1.65m - 1.90m, BMI 18.5 – 24.9, right-handed) and utilize mobile EEG, full-body motion tracking, and eye-tracking. The whole paradigm will take place outside in natural terrain under real-world conditions.

As we want to investigate motion control under real-world conditions, participants will be walking in three terrains with increasing demands for the locomotor system. They will encounter a) pavement (low demands), b) rocky terrain (medium demands), and c) forest path (high demands) sections on a continuous 4.2km long trail. Instead of the presentation of an additional visual task for event-related potential calculation, spontaneous eye-blink activity will be used to segment EEG data. Using eye-blink related potentials it will be possible to measure and compare cognitive processes and task demands across the walking conditions.

Hypotheses: Resources of information processing, measured by means of blink-evoked potential components, should be allocated to locomotion-relevant processes in natural surroundings, especially when information acquisition is meaningful for locomotion. We also expect to find a reduced P3 amplitude with increasing task difficulty.

Key words: mobile EEG, motion tracking, eye tracking, naturalistic setups

POSTERS

Collected data

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Berlin Mobile Brain/Body Imaging Lab

Auditory processing is modulated by active sensing during walking

Chen, Xinyu [1,2]; Cao, Liyu [2,3]; Prada, Juan [4]; Haendel, Barbara [1,2]

1: Neurology department, University Hospital Würzburg, Würzburg, 97080, Germany;
2: Department of Psychology (III), Julius Maximilians Universität Würzburg, Würzburg, 97070, Germany;
3: Department of Psychology and Behavioural Science, Zhejiang University, Hangzhou, 310007, China;
4: Department of Bioinformatics, Julius Maximilians Universität Würzburg, Würzburg,97074 Germany

Active sensing refers to a sensory system's capability to gather information from the environment by actively probing or manipulating it. We set out to understand if such an active process modulates auditory sensing during ongoing locomotion in humans. We conducted two experiments using mobile EEG during free walking. In experiment 1, participants walked in a pre-defined path with continuous auditory entrainment at different frequencies for the left and right ear. In experiment 2, they additionally listened to central vs. peripheral auditory disturbances (burst tones). The neural responses induced by disturbances and the auditory steady-state response (ASSR) were analyzed dependent on the walking direction.
Only a peripheral auditory perturbation induced a stronger neural response (ASSR modulation and auditory ERP) during walking compared to standing while a central auditory input led to a comparable neural response during walking and standing. Those findings indicate enhanced peripheral processing in audition during walking, mirroring observations previously shown in vision. We further found a significant modulation of the peripheral auditory entrainment strength dependent on walking direction. The more strongly entrained side consistently followed the overall direction of the turn.
Overall, our studies indicate that auditory processing is modulated by locomotion in two ways: 1) walking enhances peripheral processing compared to central processing; and 2) ongoing peripheral auditory processing is influenced by the walking path, potentially optimizing navigation and suggesting a shift in attention. We argue that this is based on processes of active sensing.

Key words: Auditory processing; Active sensing; Peripheral information processing; Walking; Attention

Embodied Hyperscanning: Heartbeat Evoked Potentials during social interaction

Grasso Cladera, Aitana [1]; Parada, Francisco J. [2]

1: Cognitive Science Institute, Osnabrück University, Germany;
2: Centro de Estudios en Neurociencia Humana y Neuropsicología, Universidad Diego Portales, Chile

Cognition can be understood as an embodied and environmentally scaffolded phenomenon. Hence, cognitive processes should be studied addressing their relationship with the agents' entire biology and their environments. In this sense, several hypotheses have been developed in order to explain the pathways and characteristics of the inter-system relations within the nervous system (e.g., gut-brain or heart-brain axes). Cardiac activity, especially the Heartbeat Evoked Potential (HEP), has been used as a biomarker for heart-brain communication through the vagus nerve. While extensively studied in the context of interoceptive abilities and clinical populations (e.g., depression, anxiety), HEP has not been explicitly employed to explore social interactions, even when interactive behaviors have an evolutionary role, as one of the most common behaviors among social species, and might impact health-disease processes. Here, we use a Mobile Brain/Body Imaging setting to conduct the first embodied hyperscanning to study HEP dynamics in dyads playing the "Rock-Paper-Scissors" (RPS) game. While participants were playing the game, brain and cardiac activity were collected by electroencephalography (EEG) and electrocardiography (ECG), respectively. Results will show the feasibility of studying brain activity in the light of bodily dynamics during social interactions. In this exploratory study, we expect to see synchrony and similarity in terms of HEP amplitude in the dyads. This is a step forward for the integration of first-, second-, and third-person approaches in neuroscience research.

Key words: Embodied Hyperscanning, Social Interaction, Heartbeat Evoked Potentials

Comparison of the electrocortical dynamics and neural substrates in real-world table tennis and Pong video game play

Hauge, Theresa Christine [1]; Ferris, Daniel P. [2]; Seidler, Rachael D. [1]

1: Department of Applied Physiology & Kinesiology, College of Health & Human Performance, University of Florida, United States of America;
2: J. Crayton Pruitt Family Department of Biomedical Engineering, Herbert Wertheim College of Engineering, University of Florida, United States of America

Recent studies using mobile EEG technologies during table tennis have revealed insights into cognitive, sensorimotor, and parietal processes previously reported in video game EEG research. Table tennis and video game play [1] [2], [3], [4], [5], [6] induce greater frontal theta activity, suggesting engagement of similar cognitive control processes during video game play and table tennis. Visual stimuli presented on a computer screen produce analogous visual-evoked potentials as the visual stimuli in table tennis in midtemporal visual areas [7], and skilled table tennis players and video gamers exhibit similar alpha power modulations associated with visual information processing during visuomotor tasks [8], [9], [10], [11] and error-detecting [12], [13], [14]. Studies also indicate greater bilateral sensorimotor alpha / beta power during table tennis serves and hits [2] relative to standing baseline, echoing sensorimotor and parietal neural correlates of complex video game play [3], [15]. Despite the similarities in underlying processes of the two, there has been no direct comparison of event-related spectral dynamics between table tennis and video game play. We investigated this here by recording participants' electrocortical activity during games of table tennis and the video game Pong, both against a human opponent. We hypothesized that the task demands of table tennis play would elicit greater spectral power changes in prefrontal, parietal, and sensorimotor brain areas compared to Pong, reflecting that table tennis and video game play may utilize similar brain regions in physical or virtual game environments. Data will be analyzed and discussed at the presentation.

Key words: table tennis, video game, cognitive resources, sensorimotor contributions, task demands

EEG recording during basketball free-throw shooting – Is there a signal in all the noise?

Hinneberg, Britta M. [1]**; Junge-Bornholt, Lea E.** [1]**; Maurer, Heiko** [1]**; Maurer, Lisa K.** [1,2]**; Müller, Hermann** [1,2]**; Hegele, Mathias** [1,2]

1: nemolab – Neuromotor Behavior Laboratory, Justus Liebig University Gießen, Germany;
2: CMBB – Center for Mind, Brain and Behavior, Universities of Gießen and Marburg

In recent years, EEG has been increasingly used in mobile settings. However, its use in sports contexts or during large and fast whole-body movements remains challenging, mainly due to major artifacts introduced by such movements. One attempt to correct for these artifacts is the dual-layer EEG approach by Nordin and colleagues (2018). In this setup, an additional EEG system is used inside-out on top of the normal scalp EEG to measure only artifacts. These data can then be used as a reference to clean the scalp EEG data from the movement artifacts. However, to date, there is no best practice on how to use the data from the outer “artifact” EEG layer to clean the scalp layer data.
In the present study, we analyzed EEG data from 30 expert basketball players recorded during free-throw shooting using the dual-layer approach. In experts, who should have very good internal forward models, an increase in theta power and an ERN would be expected shortly after or even during a goal-directed movement and, importantly, before the final outcome of a movement can be observed. We investigated whether these neural correlates of error prediction and monitoring can be isolated in the data when second-layer data are used to correct for the large motion artifacts. We tested and compared different approaches, thereby contributing to the ongoing discussion of best practices for such dual-layer methods.

Key words: dual-layer EEG, error prediction, ERN, theta oscillation, artifact correction

Effects of Different Types of Acute Physical Exercise as compared to Sitting on Memory Performance and Brain Activity measured by Mobile EEG

Klapprott, Melanie [1]; Debener, Stefan [1,2,3]

1: Carl von Ossietzky Universität Oldenburg, Germany;
2: Cluster of Excellence Hearing4All, University of Oldenburg, Germany;
3: Fraunhofer Institute for Digital Media Technology IDMT, Oldenburg Branch for Hearing, Speech and Neurotechnology, Oldenburg, Germany

Mobile electroencephalography (EEG) enables the study of brain-electrical activity during natural human behavior such as walking or cycling, and even swimming. Previous work showed that physical exercise can have positive effects on cognitive performance and affects various measures of brain activity. Here we test whether acute bouts of swimming and cycling have beneficial effects on memory performance and influence event-related potentials (ERPs) in contrast to a control condition (sitting and watching a video), using a between-subjects pretest posttest design. In an exploratory analysis, we will draw comparisons between the effects of the different types of physical exercise. During the whole experiment, we record brain activity using mobile EEG and the heart rate using a commercial heart rate monitor and a smart watch. For the swimming condition, we use a custom mobile EEG cap with a head-mounted wireless amplifier, made waterproof with a silicone cap and medical tape. For the other conditions, we use standard mobile EEG caps. Participants are given a subsequent memory task before and after the intervention (20 minutes of swimming, cycling, or sitting), with the whole experiment and EEG data collection running on a smartphone.
Upon abstract submission, a part of the data was already recorded. Until the poster presentation, we expect to have finished most, if not all parts of the data analysis. The focus will lie on ERPs recorded during the subsequent memory paradigm and the distractor task (a Go/NoGo paradigm) and time-frequency analyses during the interventions.

Key words: mobile EEG, physical exercise, memory, ERPs

When sound becomes noise – the influences of stimulus, context and listening mode on auditory perception

Korte, Silvia [1]; Jaeger, Manuela [1]; Rosenkranz, Marc [1]; Bleichner, Martin G, [1,2]

1: Neurophysiology of Everyday Life Group, Department of Psychology, University of Oldenburg, Germany;
2: Research Center for Neurosensory Science, University of Oldenburg, Germany

The experience of noise extends beyond the physical attributes of a sound. Individual perception of a sound is intricately linked to personal factors, including attention, momentary context, and many others. In a comprehensive long-term EEG study of 6 hours, we explored how the naturalness of stimuli, context, and listening mode influence the brain's response to sounds.
Our experiment comprised three phases. Initially, we recorded 23 participants' baseline responses as they passively listened to either artificial (beep tones) or natural sounds (soundscape of a busy city) while engaging in a non-auditory secondary experimental or natural task. This illuminated the roles of stimulus naturalness and task context. Moving to the second phase, participants engaged in actively listening the auditory material while responding to specific aspects of it and concurrently performing the same secondary tasks. This allowed a comparison between passive and active listening for artificial as well as naturalistic soundscapes, providing insights whether neural processing differs with differing naturalness of sounds. In the final phase, tasks were revisited in passive listening mode to observe whether the brain response returned to baseline when the previously relevant stimulus was reintroduced.
Data analysis was conducted on an individual basis for each subject. Brain responses during different phases were quantified as event-related potentials, with a focus on the P300 component, or as temporal response functions to the ongoing soundscape. We will present results of this multifaceted approach showing the nuanced interplay of naturalness, context, and listening mode in shaping the neural response to auditory stimuli.

Key words: Auditory Perception, ERP, TRF, Attention, Natural sound

Time-synchronized streaming of smartphone sensor signals

Maanen, Paul [1]; Stritzke, Anouk [2]; Blum, Sarah [3]; Roheger, Mandy [2]; Debener, Stefan [1]

1: Neuropsychology Lab and Cluster of Excellence “Hearing4all” , Department of Psychology, School of Medicine and Health Science, University of Oldenburg, Oldenburg, Germany;
2: Ambulatory Assessment in Psychology Lab, Department of Psychology, School of Medicine and Health Science, Carl von Ossietzky University, Oldenburg, Germany;
3: Hörzentrum Oldenburg gGmbH, Oldenburg, Germany

Modern smartphones house numerous sensors with significant research potential, particularly in mHealth and mobile neuroscience. However, integrating sensor data from different devices poses synchronization challenges. We have developed two Android apps: SENDA streams smartphone sensor data via a local network, and RECORDA, which records and synchronizes these data streams.
The latest SENDA version includes three enhancements: Inclusion of location data streaming, integration of Movella DOT body-worn motion sensors, and streaming of the output features of the camera-based Google MediaPipe hand landmarker, pose landmarker as well as the MediaPipe audio classifier. The audio classifier is integrated as part of SENDA, while the pose and hand landmarker are implemented as standalone apps.
To validate the technical functionality and showcase the practical applications of these new features, we will present a technical validation dataset where we validated the new features in terms of functionality and precision. As example use cases we also present data collected in two studies: In the first study we utilized SENDA and a purpose-built companion app to record typical orientation behavior during a wayfinding task in a naturalistic setting. In the second study we employed the MediaPipe hand landmarker to live stream a subject’s hand position while concurrently recording EEG and EMG data in a go/no-go paradigm, allowing us to compare the viability of the hand landmarker for trial rejection with trial rejection via EMG. During the poster presentation, we will also provide a live demo showcasing the apps’ functionality on a standard smartphone.

Key words: Smartphone Sensors, mHealth, Sensor Data Integration, Mobile Neuroscience, Android Apps

Monitoring the Dynamic Interplay of Frequency-Specific Multiplex EEG Brain Networks and Heart Rate Dynamics at the Onset of Epileptic Seizures

Markovič, Rene [1,2]; Šterk, Marko [1,3]; Paradiž Leitgeb, Eva [3]; Stožer, Andraž [3]; Krajnc, Natalija [4]; Gosak, Marko [1,3,5]

1: Faculty of Natural Sciences and Mathematics, University of Maribor, Slovenia;
2: Faculty of Electrical Engineering and Computer Science, University of Maribor, Slovenia;
3: Faculty of Medicine, University of Maribor, Slovenia;
4: General hospital Slovenj Gradec, Slovenia;
5: Alma Mater Europaea ECM, Slovenia

Coordinated interactions among organs are crucial for generating distinct physiological states, functions, and preserving overall health. These include wakefulness, sleep and its stages, rest and exercise, stress and anxiety, and cognition. Disruptions in the communication between organs can lead to dysfunction and can trigger a cascade of failures, resulting in the breakdown of the entire organism. While considerable strides have been made in systems biology and integrative physiology, the principles governing dynamic interactions among diverse human body systems, their integration, and their role in generating physiological states in health and disease remain largely elusive. The emerging interdisciplinary field of Network Physiology seeks to tackle these fundamental inquiries. In the present contribution we demonstrate how this recent framework can be used to study correlated changes in heart rate and brain activity. Analyzing 21-channel scalp electroencephalograms and electrocardiogram recordings, functional multilayer networks were constructed, representing different frequency bands. Our preliminary results demonstrate pronounced changes in alpha and theta bands during seizure onsets, with significant correlations between brain network density and heart rate parameters, particularly in delta activity. Notably, these alterations precede clinical seizure onset by 2-4 seconds. Our study highlights the importance of examining epileptic brain and heart rate activity through a network physiology perspective, providing novel insights into seizure processes. Moreover, we contend that the applied framework, rooted in network physiology approaches, holds significant relevance beyond epilepsy, extending to the analysis of human brain activity during active movements and related studies in mobile brain/body imaging.

Key words: EEG, ECG, functional brain networks, network physiology, multilayer networks

The Role of Sensorimotor Beta Power in Perceptual-Motor Interactions and Balance Impairments in Parkinson's Disease

Monaghan, Andrew S. [1,2]**; Mirdamadi, Jasmine L.** [2]**; Protzak, Janna** [1,2]**; Borich, Michael R.** [2]**; Ting, Lena H.** [1,2]

1: Emory University, United States of America;
2: Georgia Institute of Technology

We lack a mechanistic understanding of the neural and biomechanical changes that cause impaired balance control in PD. We aim to identify neural signatures of perceptual-motor interactions underlying balance impairments and demonstrate how they affect the muscle coordination of balance control in PD. Reacting to maintain balance involves the integration of multiple sensory inputs to coordinate movements across various joints. Greater sensorimotor cortical beta power is related to worse perception in young adults. There are strong associations in PD between worse whole-body motion perception during balance perturbations and lower clinical balance scores. Poorer perception may also result in a reduced ability to activate directionally specific muscle activity in response to balance perturbations, resulting in abnormal antagonist muscle activity causing joint stiffening, contributing to balance impairment in PD. However, while we know beta power is elevated in PD, it is unclear if sensorimotor beta power mediates impairments in perception, muscle activity, and balance in PD. We hypothesize that sensorimotor cortical beta power plays a role in processing sensory information crucial for perception and balance. We will measure beta power in motor cortical regions and muscle activity during balance disruptions and a whole-body directional perception task. Balance outcomes will include MiniBESTest scores and center of mass excursion post-perturbation. We predict that increased sensorimotor beta power contributes to poor balance in PD by reducing whole-body perception and increasing antagonist muscle activity, resulting in rigid balance responses following perturbations.

Key words: Parkinson Disease, Perception, Motor, Posture

Electrocortical Dynamics Related to Intermittent Visual Occlusions at Different Walking Speeds

Morris, Jonel Raven; Ferris, Daniel Perry

Univeristy of Florida, United States of America

Visual processing plays an essential role in the control of posture and gait, but we have little understanding of how the human brain processes the flow of the visual environment during locomotion. Mobile EEG data indicate that increases in walking speed affect spectral power in brain areas involved in motor control (e.g., somatosensory, parietal, anterior cingulate, and motor cortices), have little effect on the simultaneous performance of cognitive tasks, and suppress auditory electrocortical responses. As these studies have examined humans walking on treadmills with mismatches between visual flow and body movement, there is a need to determine how the flow of natural visual environments affects the processing of visual stimuli during walking. I recorded high-density dual-layer electroencephalography (EEG) of 30 participants as they walked overground and on a treadmill with a simulated visual environment at four different speeds (0.4, 0.8, 1.2, and 1.6 m/s). In all conditions, participants experienced intermittent visual occlusions to challenge the visual system. After identifying brain sources using independent component analysis and source localization, I will calculate the event-related spectral fluctuations during walking with and without the occlusion. I hypothesize that faster walking speeds will have decreases in electrocortical alpha and beta frequency power in the posterior parietal and occipital cortices. I also expect that treadmill and overground conditions will have differences in electrocortical responses to occlusions. The findings from this study will provide important insight into how movement of the body and visual environment affects the processing of visual challenges during locomotion.

Key words: visual occlusions, speed, EEG, overground, dual-layer

Automated EEG Electrode Digitization using 3D Surface Scans

Shirazi, Seyed Yahya

University of California San Diego, United States of America

Electroencephalography (EEG) source imaging offers insights into the spatial origins of brain activity. The precision of source localization depends on the accuracy of the underlying information and models, including the accurate digitization of EEG electrode positions on the scalp (i.e., electrode digitization). Traditional methods of electrode digitization, while effective, often demand time-consuming manual work and are prone to human error. Using 3D scanners has been an effective alternative for electrode digitization. Yet, the scans require manual digitization of the electrodes after data collection. We introduce an innovative approach to automate the digitization process of EEG electrodes using 3D surface scans of the head, enhancing the accuracy and efficiency of source imaging analyses. We designed a framework that employs systematic viewpoint projections around the head's surface to capture 3D data, enabling automated identification of electrode positions through image processing. This process includes converting 3D scans into 2D projections from multiple viewpoints, ensuring complete coverage of the scalp's surface, and employing color-based template matching for electrode recognition. The recognized patterns would then be transformed back into the 3D space while accounting for potential duplicate electrodes. Lastly, the experimenter is asked to verify the digitized electrodes and annotate potentially missed locations. By automating electrode digitization, researchers can achieve a higher resolution of EEG source imaging in less time. Coupled with the general availability of 3D scanners through smartphone technologies, we hope that this tool facilitates a more detailed and accurate exploration of EEG activities and their corresponding brain regions.

Key words: source imaging, spatial accuracy, electrode position

Decoding exercise-induced fatigue: A planned study for the role of brain neurotransmission

Arenales Arauz, Y. Laurisa [1]; Mali, Ana [1,2]; Habay, Jelle [1,3,4]; Marusic, Uros [2,5]; De Pauw, Kevin [1,6]; Roelands, Bart [1,6]

1: Human Physiology and Sports Physiotherapy Research Group,Belgium;
2: Institute for Kinesiology Research, Science and Research Centre Koper, Koper, Slovenia;
3: Research Foundation Flanders (FWO), Brussels, Belgium;
4: Vital Signs and Performance Monitoring Research Unit, LIFE Department, Royal Military Academy, Brussels, Belgium;
5: Department of Health Sciences, Alma Mater Europaea-ECM, Maribor, Slovenia;
6: BruBotics, Vrije Universiteit Brussel, Brussels, Belgium

Introduction. Exercise-induced fatigue is a multifaceted phenomenon, characterized by both central and peripheral components. Evidence suggests that alterations in brain monoamine synthesis and metabolism contribute to the central component of exercise-induced fatigue. However, the precise mechanisms underlying this process remain elusive. Hence, our aim is to explore the role of dopamine and noradrenaline through the use of reuptake inhibitors, examining their impact on exercise-induced fatigue.
Methods. This study will adopt a randomized triple blinded cross-over design with eighteen healthy participants aged 18-35 years. Following the familiarization trial, participants will undergo two conditions with reuptake inhibitors (dopamine: 8mg Methylphenidate; noradrenaline: 20mg Reboxetine) and one placebo (lactose: 10mg) condition. Fatigue will be induced through a leg extension task until exhaustion at an individualized resistance. Throughout the fatigue protocol, electroencephalograms and electromyograms will be recorded to establish a connection between cortico-muscular pathways. Simultaneously, an electrocardiogram will monitor the QT-slope/RR-interval and heart rate, while assessing perceived fatigue and exertion levels. Key performance metrics will include the number of extensions. To assess the impact of fatigue pre-post exercise, we will examine lactate levels, perceived fatigue, response inhibition and the contractile properties of the vastus medialis using tensiomyography.
Planned analyses. A general linear mixed model will discern the extent of differences in subjective, physiological, and behavioral responses under the three experimental conditions. An automated pre-processing pipeline will precede to explore brain dynamics, including motor-related cortical potentials, spectral power, and source localization techniques. Statistical analyses will be performed in R (v4.1.2), with significance set at $p<0.05$.

Key words: Exercise-induced fatigue, Leg extensions, Brain neurotransmission, Dopamine, Noradrenaline

POSTERS

Planned Studies

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Advances in Wearable High Density fNIRS for Mobility Studies

Boas, David [1]; Zimmermann, Bernhard [1]; O'Brien, Joe [1]; Carlton, Laura [1]; Muhvich, Johnathan [1]; Behrendt, Jacqueline [2]; Yücel, Meryem [1]; von Lühmann, Alexander [2]

1: Boston University, United States of America;
2: Technical University of Berlin, Germany

We have created a wearable high density fNIRS system with 56 sources and 144 detectors that covers the whole head with a hexagonal arrangement of optodes permitting measurements at 18mm and 33mm. We call this system ninjaNIRS22. The first part of this poster will cover the technical details of this ninjaNIRS22 system and its wearability. The second part of this presentation will cover the initial studies we are doing with this new system. In particular, we are investigating novel approaches for handling fNIRS artifacts that arise during walking and changes in posture (e.g. sitting versus standing versus leaning over). Exploiting the >1100 measurements spanning the entire head, we are investigating the utility for ICA for filtering motion related artifacts from the fNIRS brain signals of interest. We are comparing those results with existing filtering methods that act on single channel data. We are collecting a new dataset with our ninjaNIRS22 which introduces various motion artifacts allowing us to quantitatively compare the performance of ICA against existing channel-based artifact filter methods. This work will be followed by application to numerous mobility studies in everyday world settings.

Key words: wearable high density fNIRS hardware, filtering artifacts

Individualised performance in a whole-body motor sequence learning task

Chan, Russell Weili [1]; Likens, Aaron [2]; Bongers, Raoul [3]; Verwey, Willem B. [1]

1: Faculty of Behavioural, Management and Social Sciences, University of Twente, The Netherlands;
2: Department of Biomechanics, University of Nebraska Omaha, United States;
3: Faculty of Medical Sciences, University of Groningen, The Netherlands

Fundamental research in motor sequence learning has typically relied on the use of fingers to uncover neurocognitive mechanisms. In recent years, there has been a shift towards more whole-body tasks to truly understand the 'motor' aspect of sequence learning. In the current proposed research, we will utilize a successfully ported whole-body version of a popular sequence learning paradigm called the Discrete Sequence Performance (coined Body-DSP) task. We plan to vary the difficulty of the Body-DSP task using different sequence lengths from 6-12-18 items to determine if participants use different strategies to perform the task due to individual limitations in working memory. We predict that if this is true, then different concatenation points (items whereby response times are slower) will arise between participants. This will also be coupled with higher cortical activations for participants who learn the sequence more poorly than those who learn the sequence better. Our goal of this research is to unravel both neurocognitive and behavioural differences at an individual level with the long-term goal of providing idiosyncratic training approaches.
Data collection will be multimodal and involve the use a mobile EEG set (ANT Neuro eego™sports), Movella's MTw Awinda (inertial-based kinematics), behavioural performance (response times, accuracy), and self-rated questionnaires. Because of the complexity of the data, we will also perform non-linear analyses in the form of Lorenz Attractors in addition to more established linear-based representational similarity analyses. Linear approaches will help to uncover working memory mechanisms whilst non-linear approaches will showcase participants' stabilization of motor learning states.

Key words: Motor sequence learning, non-linear dynamics, EEG, kinematics, neurocognitive

How Naturalistic Music is Processed in the Brain During Dance?

Duman, Deniz [1]; Iversen, John [2]

1: University of Jyväskylä, Finland;
2: McMaster University, Canada

The current project is continuation of the prior investigation (Duman et al., 2023) and bases on two research problems: (1) Collecting brain data during motion has been a big challenge in the field of neuroscience, often causing studies to investigate brain and the body separately. (2) Despite the concept of groove and bodily movement are central aspects of music enjoyment, not much is known about the neural processing thereof. Thus, the main aim of the current work is to investigate how naturalistic (groove) music is processed in the brain during dance. Participants will first be instructed with a localiser task, during which they will (a) listen to the presented audio stimuli, (b) move specific parts of their body (such as hands and feet) in silence, (c) listen to the presented audio stimuli and move their body while we record EEG. Secondly, participants will perform either passive ("listen to the audio clips and do not move or imagine moving") or active ("follow the audio clips with your body movements") conditions while EEG and motion capture data will be collected simultaneously. There will be both naturalistic musical excerpts and their respective drum and bass reconstructions (including various levels of groove). Importantly, with a combination of pre-processing (Artifact Subspace Reconstruction) and analysis (Independent Component Analysis) methods, we target at separating brain signal from other sources. Overall, this project would not only increase our knowledge about the neural underpinnings of sensory-motor synchronisation, but also lead to methodological advancement.

Key words: groove, music, embodiment, mobile EEG, motion capture

Neuronal correlates of hyperbolic discounting in multi-attribute decision making task: an exploratory EEG study

Grabowska-Chenczke, Olga [1]; Kiryluk-Dryjska, Ewa [2]; Rani, Anshu [3]

1: Poznan University of Life Sciences, Poland;
2: Poznan University of Life Sciences, Poland;
3: Poznan University of Life Sciences, Poland

This study investigates the neuronal correlates of hyperbolic discounting in the context of multi-attribute decision making through an exploratory EEG approach. Hyperbolic discounting, characterized by a preference for smaller, immediate rewards over larger, delayed ones in a non-linear fashion, is a crucial phenomenon with significant implications for decision-making and economic behavior (Lempert, 2015).
Utilizing a Brain Product brand, ActiCHamp model,GmbH, 32 channel EEG device and EEG cap designed with 10-20 electrode connection system, the research aims to capture and analyze the real-time neural activity associated with hyperbolic discounting during delayed risky decisions performed by 40 healthy human adults. The study will allow for the identification of specific neural signatures linked to cognitive processes involved in evaluative categorization.
The study focuses on uncovering the temporal dynamics and spatial distribution (4 ERP components namely P200, N2, P300, LPP) of neural responses as participants engage in decision-making scenarios that involve trade-offs between immediate and delayed rewards across multiple attributes (amount of reward, time delay, reward probability and desirability). Discussing two competing models of delay and probability discounting (mulitplicative and additive) (Wang et al., 2020) the study represents a novel contribution to the understanding of the neural mechanisms that drive the brain economic valuation system (Tyson-Carr, 2019; Zhao et al., 2018).
The findings have the potential to enhance our comprehension of the neural basis of multiple attributes perception in decision-making task and may inform future research on cognitive interventions or decision-support strategies aimed at mitigating the impact of hyperbolic discounting in various practical domains.

Key words: delay, probability, discounting, decision-making, ERPs

Learning the impossible: investigating the organisation of spatial knowledge using virtual non-Euclidean spaces

Hilton, Christopher; Gramann, Klaus

Technical University of Berlin, Germany

Information about the spatial structure of the environment is constantly sampled via several sensory streams as humans move through space. This information is integrated and stored in memory for later use when navigating the same environment in the future. It has long been accepted that there is an organisational structure to spatial memory, however the format and underlying principles that govern spatial memory are still a topic of debate (Peer et al., 2021). In the planned study, we will utilise an impossible space paradigm to present participants with environments that do not comply with the laws of Euclidean space to test predictions from two key theories of spatial knowledge organisation: the Euclidean cognitive map, or a labelled cognitive graph. Participants will actively traverse the environments presented in virtual reality using a head-mounted display. Metric information derived from movement will conflict with visual landmark information regarding the participants' position in the environment during the learning phase. Subsequent test phases will reveal behavioural indicators of the spatial knowledge that is encoded by participants, and the manner in which different types of knowledge have been integrated. Further, in order to understand how the conflicting sensory streams are resolved and to compare processing of Euclidean vs non-Euclidean environments, we will record concurrent high-density electroencephalography and eye-tracking measures. The poster presentation will discuss planned analyses of this data and seek to gain feedback and develop new ideas on potential analysis avenues to address the study research questions.

Key words: spatial navigation, electroencephalography, virtual reality, non-Euclidean space

Effects of wood visual stimuli (color and pattern) on thermal perception of indoor built environments

Kalantarifard, Amir [1]; Djebbara, Zakaria [2,3]; Faizi, Mohsen [1]; Ekhlassi, Ahmad [1]

1: School of Architecture and Environmental Design, Iran University of Science and Technology (IUST), Tehran, Iran;
2: Department of Architecture, Design and Media Technology, Aalborg University, Aalborg, Denmark;
3: Biological Psychology and Neuroergonomics, Technische Universität Berlin, Berlin, Germany

The thermal perception of indoor built environments is a multifaceted phenomenon influenced by the integration of various sensory stimuli. Visual stimuli wield a profound impact on human perception extending to neural processes too. This study investigates the influence of visual stimuli derived from indoor wood aesthetics on occupant thermal perception and attentional performance University's audio-visual laboratory. The room temperature and relative humidity are monitored and stabilized within the thermal comfort zone. We expect to recruit twenty-four university students (12 men and 12 women) with a similar native origin climate in their 20s and 30s. Using Virtual Reality (VR), participants will be presented with nine distinct appearances of wooden environments (3 Colors × 3 Patterns). A 30-minute thermal adaptive phase upon entering the laboratory is integrated with the mounting of the electroencephalography (EEG) setup. Participants are exposed to the experimental environments for 6 minutes with a VR baseline environment integrated between each condition to eliminate the short-term perception effects. An additional 30 seconds before exposure to the experimental condition is introduced to ensure adaptation before conducting a visual P300 test for 5 minutes. Towards the end, participants will answer a VR thermal sensation and perception questionnaire as a subjective evaluation of thermal perception. Due to the hue-heat hypothesis, we expect to find a warmer thermal perception of colors closer to the red-orange-yellow hues. We also expect to find differences between P300 behavioral performances and the event-related potentials. We anticipate demonstrating the effects of visual stimuli on thermal perception.

Key words: visual stimuli, thermal perception, EEG, Virtual reality, Neuro-Architecture

A Multi-Modal Study of a Touchscreen Visual Working Memory Task: A Mobile Brain/Body Imaging (MoBI) Study

Kim, Jeehyun; Mantel, Emma P.; Foxe, John J.; Freedman, Edward G.

The Frederick J. and Marion A. Schindler Cognitive Neurophysiology Laboratory, Department of Neuroscience and The Del Monte Institute for Neuroscience, University of Rochester School of Medicine and Dentistry, Rochester, NY, USA

Visual working memory (VWM) is a limited capacity system crucial for temporarily maintaining, updating, and manipulating visual information. Prior lateralized VWM task paradigms have focused on Contralateral-Delay-Activity (CDA) as a neurophysiological marker for VWM maintenance capacity. However, limited studies have integrated VWM with everyday movement, prompting the development of a touchscreen VWM task. This project aims to replicate and extend past findings, exploring the subprocesses involved in VWM and movement, with a focus on establishing task-specific multi-modal markers. Participants without neurological and movement impairments will complete a touchscreen VWM task involving arm reach-and-tap responses. The task includes cognitive trials with varying demands (i.e., from 1 to 4 memory items) and motor-only trials for cognition-free pointing accuracy. Mobile brain/body imaging (MoBI) technology will capture time-synchronized behavioral performance (task responses), neurophysiological activity (electroencephalogram), and arm kinematics (3D motion tracker) data. In terms of behavioral performance, we hypothesize a decline in performance with increasing cognitive demand, evidenced by a greater distance between response and target locations as the number of memory item rises. In terms of neurophysiological activity, we primarily expect this paradigm to replicate the CDA amplitude increase with the number of memory items, correlating with behavioral performance. In terms of kinematics, we anticipate velocity changes during target approach as cognitive demand increases. Validating multi-modal markers from this paradigm will enhance our understanding of the neural processes underlying the integration of cognition and movement in our everyday life, and further extend to investigating neurological diseases impaired in these domains (e.g., Parkinson's disease).

Key words: Electroencephalogram (EEG), Event-Related Potential (ERP), Mobile Brain/Body Imaging (MoBI), Working Memory

Effects of interaction on movement and flow in improvising jazz musicians

Klein, Lucas Taylor; Wood, Emily; Bosnyak, Dan; Trainor, Laurel J.

McMaster University, LIVELab, Canada

Improvising musicians rely on visual and auditory cues from their partners to determine what and how to play. This creates a bi-directional feedback loop in which each musician's playing influences all the others, and vice versa. Group music improvisation can also produce an experience of deep absorption and enjoyment called "flow," or "group flow" in interactive contexts.
This planned study will explore how auditory coupling between improvising pianists affects communicative body movements, performance quality and subjective experiences of group flow. In the "coupled" condition, pairs of professional jazz pianists will improvise together without seeing each other, while we record their sound and body movements using motion capture. In the "uncoupled" condition, they will (unbeknownst to them) play with a recording from a previous pianist. The coupled condition allows for mutual (bi-directional) adaptation, while the uncoupled condition only allows adaptation in one direction (uni-directional adaptation).
We expect that information flow (indexed using Granger causality) between the pairs' motion (anterior-posterior body sway) and sound (amplitude envelope and spectral flux time series) will reflect the direction of feedback in the uncoupled condition (from the recording to the live performer), and bi-directional information flow and performance quality will be higher overall in the coupled condition compared to the uncoupled condition. We also expect musicians to report pronounced experiences of group flow in the coupled condition. The results will contribute to an understanding of the connection between modes of interaction, musical communication, and group experiences.

Key words: music, flow, improvisation, motion capture, Granger causality

Towards real-world neuroscience approaches in mild cognitive impairment (MCI): Study protocol using Mobile brain-body imaging (MoBI)

Kulashekhar, Shrikanth [1,2]; Koivisto, Anne [3]; Marušič, Uroš [4]; Röning, Juha [5]; Renvall, Hanna [1,2]

1: Aalto University, Helsinki, Finland;
2: BioMag Laboratory, Helsinki University Hospital, Finland;
3: Department of Clinical Neurosciences, University of Helsinki, Finland;
4: Institute for Kinesiology Research, Science and Research Centre, Koper, Slovenia;
5: Biomimetics and Intelligent Systems Group, University of Oulu, Finland

Mild cognitive impairment (MCI) is a condition between normal brain aging and dementia. Around 50% of people with MCI will develop dementia, especially Alzheimer's Disease (AD). Underlying a need for sufficient, early screening of dementia risk and intervention in our ageing population. MCI patients' show deficits in gait performance and spatial navigation behaviour that can be central to the diagnosis of pre-dementia and dementia. Since, resting electroencephalography (EEG) is restricted to immobile laboratory environment it is limited in investigating gait and navigation behaviour.
Here, we will use mobile brain-body imaging (MoBI) based, combined EEG and electromyography (EMG) to study the brain-body dynamics in MCI and AD. In the first study, gait performance is investigated with walking in naturalistic and treadmill conditions. While a second study will test spatial navigation capacity using real floor and virtual-reality maze tasks. MoBI data is acquired in both studies from healthy and patient groups. Spatio-spectral features underlying motor behaviour, as indexed by frequency-amplitude dynamics and connectivity measures are tested within and between the two groups. Further, with machine learning approaches, such as Bayesian reduced-rank regression modelling, high-dimensional MoBI data will be reduced into low-dimensional, predictive neuronal features of prodromal dementia. About 50 MCI participants will be recruited from an on-going, multi-national EU project, AI-MIND.
This project will pioneer novel brain-body approaches for easily applicable, and sensitive biomarkers in identifying MCI patients most at risk of developing clinical dementia. Research here will help understand the mechanisms underlying real-life motor and spatial navigation behaviours, and their disruption.

Key words: Mild Cognitive Impairment (MCI), Dementia, Artificial Intelligence (AI), Machine Learning, Spatial Navigation, Virtual Reality

Taking the eye-tracker out for dinner: exploring spatial attention during everyday life behaviours

Ladouce, Simon; Gillebert, Celine R.

Department of Brain and Cognition, KU Leuven, Leuven, Belgium

Hemispatial neglect is a common spatial attention deficit after unilateral stroke which remains challenging to assess in a sensitive and ecologically valid way. Current assessment methods of spatial attention lack interactions with objects embedded in the environment, despite evidence from Virtual Reality studies highlighting the importance of goal-oriented behaviors on visual exploration. In the current study, we aim to explore gaze and body dynamics during mealtime as a means of investigating embodied aspects of spatial attention in an everyday life context.
By examining the relationship between upper limb and eye movements, we hope to gain insights into attentional processes supporting action planning and deficits therein after unilateral stroke. Moreover, the investigation of spatial attention within continuous naturalistic behaviours may unveil the temporal dynamics of spatial biases. We plan to extract gaze features from continuous recordings and interpret them based on their spatialization within the environment to provide sensitive measures of spatial biases.
The extraction of features will also be object-based, considering their dynamic significance to the ongoing behaviour. These measures, along with a mapping of low-level visual features of the environment, will provide metrics to assess the influences of bottom-up and top-down factors on behaviour in everyday life. A scalable experimental design will be employed, comparing measures of spatial attention acquired during mealtime to those of classic computerized paradigms.
This research aims to enhance our understanding of spatial attention in dynamic, everyday life contexts, offering sensitive and ecologically valid measures to improve assessments and interventions for individuals facing attention-related challenges.

Key words: spatial attention, eye-tracking, gaze dynamics, embodied cognition, eating

The investigation of neurophysiological markers of false memories in mobile and virtual environment

Maciejewska, Karina Janina

University of Silesia in Katowice, Poland

Episodic memory is a reconstructive process, so it is prone to errors. This work focuses on the misattribution (false memories), i.e. recognition of events that didn't occur, or misattribution of the memory source (i.e. incorrect time, place, or person), behaviorally and subjectively indistinguishable from true memory. The aim is to find neurophysiological markers of false memories in long-term recognition memory, using mobile measurements of EEG, as well as EDA, EMG, and ECG.

Unlike most of the previous studies using biomedical signals in neuroscience, based on standard laboratory setups, where the participants are seated and observe 2-dimensional stimuli on a computer screen, we plan to make the experimental conditions resemble natural conditions in which people use memory processes and in which false memories occur. Therefore, we will perform the experiment in the virtual reality (VR) environment with mobile participants.

At encoding, the participants will walk around a VR room, visually scan the environment, and look at the objects to be remembered which will be positioned in different places in the room. At retrieval, they will be tested using the studied and new objects.

This study increases the ecological validity of the neurocognitive experiments and elicits an immersive experience in a natural environment. The misinformation paradigm used to elicit false memories resembles a real-world situation, in which an eyewitness first encounters a crime (memory encoding), then is exposed to misleading information (misinformation), and finally presents the testimony in court (memory retrieval). Therefore we see a special significance of this project in forensics.

Key words: mobile EEG, biomedical signals, episodic memory, VR, cognitive neuroscience

Dual-task effects of auditory discrimination task during walking and postural adjustments: A Mobile Brain/Body Imaging study in healthy individuals

Maiocchi, Carlotta [1]; Canessa, Nicola [1,2]; Rassouli Baghi, Leonardo [1]; Gallotta, Roberto [3]; Wunderlich, Anna [4]; Gramann, Klaus [4]; Wollesen, Bettina [5]; Gianelli, Claudia [6]

1: IUSS Cognitive Neuroscience (ICON) Center, Scuola Universitaria Superiore IUSS Pavia, Italy;
2: Istituti Clinici Scientifici Maugeri IRCCS, Cognitive Neuroscience Laboratory of Pavia Institute, Italy;
3: Institute of Digital Games, University of Malta, Malta, Malta;
4: Biological Psychology and Neuroergonomics, Department of Psychology and Ergonomics, Faculty V: Mechanical Engineering and Transport Systems, Technische Universität Berlin, Berlin, Germany;
5: Human Movement and Training Science, Institute of Human Movement Science, Psychology and Human Movement, University Hamburg, Hamburg, Germany;
6: Department of Clinical and Experimental Medicine, University of Messina, Messina, Italy.

The mutual dependence of performing concurrent motor and cognitive tasks is known to affect either or both outcomes negatively. Such "dual-task cost" (DTC) has been ascribed to the need to allocate our limited attentional resources between the two tasks, which often results in suboptimal task performance. The DTC has been studied with behavioural and neuroimaging paradigms, but the neural correlates of dual-task cost are still debated.
The present study aims to investigate the role of motor complexity on the behavioural and neural correlates of dual-tasking, through an auditory discrimination paradigm performed in different motor conditions (standing on a balance pad and walking), with "sitting" as a stationary baseline task. Based on power-analysis, 41 healthy participants will be recruited. Participants will be presented with tones of high-frequency (1000 Hz) and lower-frequency (800 Hz). The neural correlates of DTC will be investigated with a mobile 64-channel EEG system, while 5 motion sensors of the HTC VIVE system will allow recording motion capture. The cognitive performance will be analysed across conditions using a one-way repeated-measure ANOVA, while gait parameters and centre of pressure (COP) displacements will be modelled using paired sample t-tests. We expect the cognitive requirements of walking and standing on a balance pad to decrease P3 amplitude in auditory evoked potentials, compared with sitting, and modulate motor parameters, as DTC increases. Specifically, based on previous findings, we expect a decreased fronto-central theta and alpha power, as movement complexity increases, and modula-

tion of COP oscillations and spatio-temporal gait parameters.

Key words: dual-task, auditory discrimination task, MoBI, overground walking, body displacement

Research protocol: Exploring the impact of Neurotransmission on Physical Fatigue and Motor-related cortical potentials

Mali, Ana [1,2]; Arenales Arauz, Y. Laurisa [2]; Habay, Jelle [2,3,4]; Roelands, Bart [2,5]; De Pauw, Kevin [2,5]; Marusic, Uros [1,6]

1: Institute for Kinesiology Research, Science and Research Centre Koper, Koper, Slovenia;
2: Human Physiology and Sports Physiotherapy Research Group, Faculty of Physical Education and Physiotherapy, Vrije Universiteit Brussel, Belgium;
3: Research Foundation Flanders (FWO), Brussels, Belgium;
4: Vital Signs and Performance Monitoring Research Unit, LIFE Department, Royal Military Academy, Brussels, Belgium;
5: BruBotics, Vrije Universiteit Brussel, Brussels, Belgium;
6: Department of Health Sciences, Alma Mater Europaea-ECM, Maribor, Slovenia

Purpose. Motor-related cortical potentials (MRCPs) are electrical signals associated with motor planning and execution that provide valuable insights into the neural processes underlying (un)voluntary movements. Evidence suggests a reduction in MRCP amplitude corresponding to the onset of neuromuscular fatigue. However, the exact role of brain neurotransmitters in this process remains unknown. In this study, dopamine and noradrenaline reuptake inhibitors are used to investigate the role of neurotransmitters while measuring electromyography (EEG) during the onset of physical fatigue in leg extensions.
Methods. Eighteen healthy male and female subjects (18-35 years) perform one familiarization and three experimental trials (dopamine, noradrenaline, placebo) in a randomized, triple-blinded, cross-over study design. After completing the cognitive task, participants must perform a submaximal leg extension task at 40% of one-repetition maximum by responding to visual stimuli until fatigued, followed by another cognitive task. Several physiological (including EEG) and cognitive indicators (reaction time, accuracy) are examined as primary outcomes; secondary outcome measures include subjective scales and questionnaires. Electromyography data is used to detect the onset of muscle contraction. MRCPs are extracted from the EEG electrode Cz and precede actual voluntary movement, reflecting the cortical processes involved in movement planning and preparation. The data is processed using EEGLAB and a custom-made MATLAB-based pipeline.
Discussion. This protocol considers the impact of noradrenaline and dopamine reuptake inhibitors on the development of fatigue and cortical involvements evaluated through MRCP. The aim is to obtain additional information on brain dynamics by monitoring cortical (MRCPs) and beha-

vioral outcomes (reaction times, accuracy, leg extension torques).

Key words: brain neurotransmission, physical fatigue, Motor-related cortical potentials (MRCPs), Electroencephalography (EEG), leg extension exercise

Is it natural to walk on a treadmill? Dual-tasking gait effects in elderly individuals studied with mobile EEG

Papin, Lara Johanna [1]; **Debener, Stefan** [1,2,3,4]

1: Carl von Ossietzky Universität Oldenburg, Germany;
2: Carl von Ossietzky University Oldenburg, Cluster Excellence Hearing4all, Oldenburg, Germany;
3: Carl von Ossietzky University Oldenburg, Ctr Neurosensory Sci & Syst, Oldenburg, Germany;
4: Fraunhofer Inst Digital Media Technol IDMT, Branch Hearing Speech & Audio Technol HSA, Oldenburg, Germany

Balancing is a challenge we face every day, not only during complex balancing tasks but also when walking naturally (natural gait). Human balance control can be described as a feedback system, continually integrating incoming sensory inputs associated with body instability, and inducing corrective actions. Individuals may manage this more or less successfully depending on various demographic and cognitive factors. Failing balancing demands often leads to falls, potentially resulting in severe injury.
The risk of falling is exacerbated when two tasks are executed concurrently, particularly in elderly individuals. Most previous dual-tasking cognitive-motor interference studies used treadmills to implement gait, but treadmill gait may not capture the complex balancing demands of natural gait very well. Typically, interference between simultaneously executed tasks results in decreased performance in one or both tasks, but no interference or facilitation effects have been reported as well. Recent work suggests that cognitive performance can benefit from treadmill gait, whereas other studies using natural gait conditions report interference effects. Here we specifically test whether treadmill gait and natural gait have opposite effects on cognitive task performance.
We will study the cortical signatures of gait and Go/NoGo task performance under dual-tasking conditions in elderly individuals, using mobile electroencephalography (EEG), and motion tracking. The direct comparison of treadmill and natural gait effects will shed light on cognitive-motor interactions and help to identify the cognitive demands of real-world, natural behaviour.

Key words: Cognitive-Motor Interference, Dual-Tasking, Gait, Response Inhibition

An EEG exploratory study on willingness to pay (WTP) for Fair-Trade Products (FTPs) using Becker-DeGroot-Marschak auction task

Rani, Anshu [1]; Kiryluk-Dryjska, Ewa [2]; Grabowska-Chenczke, Olga [3]

1: Poznan University of Life Sciences, Poland;
2: Poznan University of Life Sciences, Poland;
3: Poznan University of Life Sciences, Poland

The consumption of FTPs is steadily increasing worldwide, establishing trading partnerships, based on dialogue, transparency and respect to promote greater equity and sustainable development in international trade. The objective of the study is to investigate the neuronal correlates of the motives behind the consumer decision to buy FTPs and identify common characteristics of the real-time neural activity associated with the WTP for FTPs.

The participants (N=60) will be recruited among healthy adults. EEG will be recorded during six blocks of the Becker-DeGroot-Marschak auction bidding task on FTPs. To examine framing effect, participants will be divided into three groups: FTPs' buyers, informed non-buyers, and uninformed non-buyers. The study will utilize a 32-channel EEG (actiCHamp Plus) with a cap equipped with a 10-20 electrode connection system by Brain Products GmbH.

The automaticity of brain valuation suggests that subjective value is likely encoded in the first instance following stimulus presentation (Tyson-Carr, 2019). Therefore, the study will focus on uncovering temporal dynamics and spatial distribution during the early exposure to the FTPs' bidding task. The study will assess the asymmetry in the engagement of the prefrontal cortex in relation to its resultant WTP responses for FTPs using the hemispheric asymmetry model (Spielberg et al., 2008). Frontal asymmetry in the Alpha band, a trend in the Beta band and prefrontal asymmetry in the gamma band will also be recorded. Additionally, cerebral activity for high-value and low-value FTPs will be identified through the assessment of latency of P3, P2, and N2 event related potential components.

Key words: Willingness to pay, BDM auction task, Fair trade product, ERPs, prefrontal asymmetry

Multimodal human-robot collaboration using cognitive processing in social and work settings

Riascos-Salas, Jaime A [1]; **Gramann, Klaus** [2]; **Fischer, Martin** [1]

1: Potsdam University, Germany;
2: TU Berlín

In recent years, there has been a surge of interest in developing human-robot collaboration systems for seamless interaction in various domains such as home assistance, healthcare, education, and industry. Utilizing electroencephalographic (EEG) signals, a promising communication alternative known as Brain-Computer Interface (BCI) has emerged. Passive BCI systems captures the involuntary brain electrical activity (EEG), allowing the inference of cognitive and emotional states. On the other hand, current robotic interfaces, relying on traditional methods like voice, touch, and facial recognition, struggle to interpret human cognitive and emotional states, hindering effective collaboration. This limitation impedes the adaptation and personalization of robots to human needs. A significant gap lies in the absence of suitable interfaces for processing cognitive signals in concordance with robotic systems. Integrating non-invasive techniques, like EEG, into complex robotics requires advanced algorithms for real-time processing, accuracy, and robustness. Moreover, building passive BCIs, especially in neuroadaptive systems involving active participant behavior or movement, creates additional difficulties. To address these challenges, we propose a multimodal interface integrating a passive BCI into the NAO robot's interaction systems. This interface combines EEG, body gestures, and voice to comprehensively capture cognitive and emotional signals. We plan to test the proposed interface in two scenarios: a workplace environment, where NAO supports users in daily activities, and a social situation, fostering interaction between NAO and users on diverse topics.. This research aims to enhance communication and mutual understanding between humans and robots, enabling more effective, intuitive, adaptive, and personalized collaboration.

Key words: Human-robot interaction, EEG, BCI, NAO

Designing Real-time Neurofeedback Games using Electroencephalography for Enhancing Cognitive Performance in Healthy Individuals and Cognitive Impaired Patients

T.A., Suhail [1,2]; Lak, Ching Cheong Davis [1,2]; Lee, Tatia M.C. [1,2]

1: State Key Laboratory of Brain and Cognitive Sciences, The University of Hong Kong, Hong Kong;
2: Laboratory of Neuropsychology & Human Neuroscience, The University of Hong Kong, Hong Kong

Neurofeedback training has emerged as a promising therapeutic tool for enhancing cognitive performance in healthy individuals and patients with cognitive disorders like attention deficit hyper activity disorder (ADHD) and mild cognitive impairment (MCI), etc. In this work, we aim to examine the effectiveness of four Electroencephalography (EEG)-based neurofeedback games in improving attention and working memory skills in healthy and patient populations. The games developed, namely "Memory-matching", "Ball-focus", "Picture-enhance", and "Flight-balance", work based on the real-time computation of attention score using EEG signals which are streamed throughout the game session. In addition, participants receive information about their cognitive states through visual feedback in the form of progress bars, ball speed, picture brightness, and airplane level within the game user-interface which motivates them to maintain and improve their attentive states throughout the game. The attention score is estimated using various approaches, including traditional EEG band ratios, Sample entropy, etc. and our proposed subject-specific attention-relevant feature selection techniques. Multiple sessions of neurofeedback training will be conducted on heterogeneous participant groups, including healthy individuals, ADHD children, and MCI adults, using different protocols. The effectiveness of the neurofeedback games will be evaluated using various EEG-based cognitive performance indices and behavioural scores. In this planned study, we anticipate that the proposed neurofeedback training protocols will be beneficial for enhancing cognitive performance in various domains for different patient populations, thereby offering new insights to the field of neurorehabilitation.

Key words: Neurofeedback, Electroencephalography, Attention, ADHD, MCI

Prospective heading influences allocation of spatial attention – A MoBI study utilizing Auditory Steady State Responses

Wieske, Roy Eric [1]; Chen, Xinyu [2]; Händel, Barbara [3]; Gramann, Klaus [1]

1: TU Berlin, Germany;
2: Institute of Psychology III, University of Würzburg, Germany;
3: Department of Neurology, University Hospital Würzburg, Würzburg, Germany

This study explores the dynamic interplay between spatial attention and auditory processing during free locomotion, employing Mobile Brain/Body Imaging (MoBI) to capture real-time neural activity and bodily movements. The auditory system's role as a gatekeeper in directing attention to salient stimuli is investigated, with a focus on auditory steady-state responses (ASSR) and frequency-tagging to assess attentional shifts. Building on the work of Chen et al. (2023), the study replicates and extends findings in a virtual reality (VR) setup, incorporating a head-mounted display (HMD) and full body- and eye-tracking. The analysis aims to track attentional shifts over time, assess differences between environments and directions, and explore path segments with increased attention. Secondary outcomes include technical implementation and concerns, analysis pipeline development, and preliminary results, addressing the replicability of previous findings and the feasibility of transferring the study to VR.

Key words: MoBI, Spatial Attention, ASSR, VR, Multimodal Integration

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ISBN 978-961-7195-56-9

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