study 1 (online list; list 2: offline list) and during delayed mixed recall of both lists in study 2.

A direct comparison of both studies showed no effect of stimulation on overall learning performance (both lists), but a generally larger loss for study 2 in contrast to study 1. A more detailed list-based analysis showed that learning performance of the offline list (study 1) had a clear advantage under theta-tACS in contrast to control. Notably, this advantage was evident in comparison to study 2, where theta-tACS actually had a detrimental effect in contrast to control. However, these findings could not be supported by neurophysiological results.

We assume that the stimulation condition-specific performance differences between on- and offline learning are a consequence of the unexpected interference of theta-tACS. According to the source-receiver approach, communication between PFC and HPC in memory formation originates only from the brain area that is supposed to receive the information. Thus, simultaneous stimulation of both in our studies may have impaired this communication.

Research Category and Technology and Methods
Basic Research: 8. Transcranial Alternating Current Stimulation (tACS)
Keywords: Memory formation, theta, learning, tACS

Abstract key: PL- Plenary talks; S- Regular symposia oral; FS- Fast-Track symposia oral; OS- On-demand symposia oral; P- Posters

OS23.3

COGNITIVE CONTROL TRAINING AND TRANSCRANIAL DIRECT CURRENT STIMULATION: A SYSTEMATIC APPROACH TO OPTIMISATION

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Abstract

Cognitive control (CC) is an important prerequisite for goal-directed behaviour and efficient information processing. Impaired CC is associated with reduced prefrontal cortex activity and various mental disorders, but may be effectively tackled by transcranial direct current stimulation (tDCS)-enhanced training. However, study data are inconsistent as efficacy depends on stimulation parameters whose implementations vary widely between studies. Objective We systematically tested various tDCS parameter effects (anodal/cathodal polarity, 1/2 mA stimulation intensity, left/right prefrontal cortex hemisphere) on a six-session CC training combined with tDCS.

Nine groups of healthy humans (male/female; n = 160 in total) received either anodal/cathodal tDCS of 1/2 mA over the left/right PFC or sham stimulation, simultaneously with a CC training (modified adaptive Paced Auditory Serial Addition Task [PASAT]). Subjects trained thrice per week (19 minutes each) for two weeks. We assessed performance progress in the PASAT before, during, and after training. Using a hierarchical approach, we incrementally narrowed down on optimal stimulation parameters supporting CC. Long-term CC effects as well as transfer effects in a flanker task were assessed after the training period as well as three months later.

Compared to sham stimulation, anodal but not cathodal tDCS improved performance gains. This was only valid for 1 mA stimulation intensity and particularly detected when applied to the left PFC.

Our results confirm beneficial, non-linear effects of anodal tDCS on cognitive training in a large sample of healthy subjects. The data consolidate the basis for further development of functionally targeted tDCS, supporting cognitive control training in mental disorders and guiding further development of clinical interventions.

Research Category and Technology and Methods
Basic Research: 9. Transcranial Direct Current Stimulation (tDCS)
Keywords: Brain stimulation, Cognitive control, tDCS, Neuropsychiatry

Abstract key: PL- Plenary talks; S- Regular symposia oral; FS- Fast-Track symposia oral; OS- On-demand symposia oral; P- Posters

OS23.4

OPTIMIZED HD-TDCS PROTOCOL FOR CLINICAL USE IN PATIENTS WITH MAJOR DEPRESSIVE DISORDER

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Abstract

Application of transcranial direct current stimulation (tDCS) has been increased in neuropsychiatric disorders, specially depression, in the last decade. Despite promising results, clinical efficacy of tDCS is still under debate and researchers and clinicians try to maximise efficacy by developing optimised/individualised protocols and/or controlling confounding variables. High-definition tDCS has recently been proposed for a more focal stimulation of targeted regions. In this randomised clinical trial, we optimised a stimulation protocol for increasing and decreasing activity in the left and right dorsolateral prefrontal cortex.

40 patients with major depression were recruited and randomly assigned to active (N=20) or sham (N=20) stimulation. Patients in each group received 30 sessions of active or sham tDCS 5 days per week. HD-tDCS protocol included 8 channels with 2 mA intensity with a maximum total current set to 4.0 mA. Symptoms severity (measure by Hamilton Depression Rating Scale- HDRS and Beck Depression Inventory- BDI) were assessed before the intervention, right after the intervention, and 1 and 3 months following the intervention. Cognitive functions (working memory, executive function, emotion recognition task) as well as resting EEG were also assessed before and after the intervention.

Compared to sham, the active tDCS group showed significantly reduced depressive symptoms up to 3 months following the intervention. Cognitive functions also improved in the active group and the intervention was associated with changes in the functional connectivity in some of the networks involved in cognitive control.

These data suggest that optimising HD-tDCS might maximise therapeutic efficacy in targeted groups.

Research Category and Technology and Methods
Clinical Research: 9. Transcranial Direct Current Stimulation (tDCS)
Keywords: HD-tDCS, Depression, tES, Modeling

Abstract key: PL- Plenary talks; S- Regular symposia oral; FS- Fast-Track symposia oral; OS- On-demand symposia oral; P- Posters

OS24.1

MULTI-MUSCLE TMS MAPPING: RELIABILITY, MALLEABILITY, CLINICAL ASPECTS, AND METHODOLOGY

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Symposium title: To map or nor to map: principles and limitation of TMS brain mapping
Symposium description: To map or not to map. That is the question. The symposium will be dedicated to TMS brain mapping, its applicability, and its limitations in a modern era of TMS armed with MRI navigation, neurophysiological monitoring, and novel coil design. In principle, TMS can be always applied to multiple spots, while the mapping type can be specified by the type of TMS protocol and type of the measured biological activity. However, presently only motor and speech TMS mapping has received widespread use. In this symposium, we will raise the question of how much TMS mapping is benefitting from the present possibilities of anatomical and physiological TMS guidance, and discuss different spatial

resolutions of the TMS mapping approach depending on a research question. We will combine the talks dedicated to the methodology and the output of the motor and non-motor cortical TMS mapping and add a non-cortical area — the cerebellum to the TMS mapping framework, discussing cerebellar TMS mapping as a possible translational model for investigating TMS cellular mechanisms. The symposium will include four talks from the Athinoula A. Martinos Center for Biomedical Imaging at Massachusetts General Hospital, Harvard Medical School, US; Max Planck Institute for Human Cognitive and Brain Sciences, Germany; and the Aalto University, Finland.

Abstract

Upper limb dexterity is one of the unique abilities of humans, which is usually compromised in patients with motor impairment. We suggest that adequate local balance among neighboring regions in the motor cortex may be one of the markers of such ability, and such balance may be non-invasively probed by means of transcranial magnetic stimulation (TMS). MRI navigated TMS (nTMS) cortical motor mapping has been FDA approved for presurgical brain mapping for more than a decade. Despite such great potential, nTMS mapping is still underused for the assessment of motor cortex plasticity, especially in clinical settings. In this talk, we will discuss the prerequisites and benefits of using multi-muscle TMS mapping for the within-limb somatotopy probing, and demonstrate the possibilities of the TMSmap (https://tmsmap.ru/), a versatile program for analyzing TMS mapping results. We will present our results of multi-muscle TMS mapping absolute and relative reliability assessment in a test-retest study in healthy subjects. Then we will present the results of the use of the same approach of multi-muscle TMS mapping to study motor cortex malleability in healthy subjects undergoing finger dexterity training. Lastly, we will discuss our results about the importance of probing motor evoked potentials (MEPs) - as a surrogate of the corticospinal tract integrity in stroke - in multiple hand muscles, to decrease the percentage of false-negative MEP patients in patients with various levels of motor impairment and time after stroke.

Research Category and Technology and Methods

Translational Research: 10. Transcranial Magnetic Stimulation (TMS)
Keywords: brain mapping, cortical mapping, motor cortex, cerebellum

Abstract key: PL- Plenary talks; S- Regular symposia oral; FS- Fast-Track symposia oral; OS- On-demand symposia oral; P- Posters

OS24.2

TMS MAPPING OF THE CEREBELLUM AS A WAY OF UNDERSTANDING TMS CELLULAR MECHANISMS

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Abstract

The human cerebellum has around 80% of the surface area of the neocortex and contains more than half of all neurons in the brain. Functionally, the cerebellum is connected with multiple cerebral regions serving motor, associative, and affective functions. Anatomically, the cerebellum is located rather superficially compared to other deeply located non-cortical brain regions, making it possible to reach it using non-invasive brain stimulation. During the last decade, the cerebellum has been reported as a promising target for therapeutic neuromodulation in a wide range of pathological conditions from spinocerebellar ataxias to schizophrenia. From a different perspective, cerebellar TMS may be a promising way to understand the cellular mechanisms of TMS because compared to cortical structures, its principal structures are arranged in a mutually orthogonal configuration invariant across species. In this study, our aim is to develop an approach to TMS cerebellar functional mapping using multiple types of neurophysiological responses, including tracing the somatotopic speci-ficity of the motor cortical modulation (e.g. cerebellar inhibition), and
behavioral modulation for the eye, limb, and swallowing (deglutition) movements. The stimulation location and orientation will be guided by individual electric field modeling and diffusion MRI tractography of the highly structural orthogonal cerebellar white matter. Moreover, our goal is to differentiate whether Purkinje cells are stimulated directly or trans-synaptically through the parallel or climbing fibers translating relative electric field thresholds for the Purkinje cells and parallel fibers activation from our ongoing in vitro TMS study on a turtle cerebellum. We hope that this type of translational study will substantially increase our knowledge of the basic mechanisms of TMS and will also be a step forward in developing effective cerebellar neuromodulation approaches in humans.

Research Category and Technology and Methods

Translational Research: 10. Transcranial Magnetic Stimulation (TMS)
Keywords: cerebellum, brain mapping, cellular mechanisms, cerebellar TMS

Abstract key: PL- Plenary talks; S- Regular symposia oral; FS- Fast-Track symposia oral; OS- On-demand symposia oral; P- Posters

OS24.3

PRECISE MOTOR MAPPING WITH TMS

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Abstract

We describe a routine to precisely localize cortical muscle representations within the primary motor cortex with transcranial magnetic stimulation (TMS) based on the functional relation between induced electric fields at the cortical level and peripheral muscle activation (motor evoked potentials; MEPs). Besides providing insights into structure-function relation-ships, this routine lays the foundation for TMS dosing metrics based on subject-specific cortical electric field thresholds.

MEPs for different coil positions and orientations are combined with electric field modeling, exploiting the causal nature of neuronal activation to pinpoint the cortical origin of the MEPs. This involves constructing an individual head model from magnetic resonance imaging (MRI) data, recording MEPs via electromyography during TMS, and computing the induced electric fields with numerical modeling. The cortical muscle representations are determined by relating the TMS induced electric fields to the MEP amplitudes. Subsequently, the coil position to optimally stim-ulate the origin of the identified cortical MEP can be determined by nu-merical modeling. Using this approach, we could distinguish cortical muscle representations of three finger muscles (FDI, ADM, APB) with high spatial resolution on the individual subject level and localized them pri-marily on the crowns and rims of the precentral gyrus. A post-hoc analysis revealed exponential convergence of the mapping with the number of stimulations, yielding a minimum of about 180 stimulations from random coil positions to obtain stable results.

Establishing a functional link between the modulated effect and the un-derlying mode of action, the induced electric field, is a fundamental step to fully exploit the potential of TMS. In contrast to previous approaches, the presented protocol is particularly easy to implement, fast to apply, and very robust due to the random coil positioning and therefore is suitable for practical and clinical applications.

Research Category and Technology and Methods

Basic Research: 10. Transcranial Magnetic Stimulation (TMS)
Keywords: TMS, Localization, Mapping, EMG

Abstract key: PL- Plenary talks; S- Regular symposia oral; FS- Fast-Track symposia oral; OS- On-demand symposia oral; P- Posters