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GENERAL SUMMARY

In a series of studies we here aim to test and modulate the functional relationship between brain oscillations and cognitive processes, induce cognitive after effect of electroencephalography (EEG)-informed individualized transcranial alternating current stimulation (tACS) in the context of memory and learning, and investigate the therapeutic potential of noninvasive neuromodulation techniques in patients suffering from cognitive impairments associated with pathological alterations in oscillatory brain activity. To this end, we recorded EEG in both, healthy and diseased human participants during the performance of various cognitive tasks. In the first study, we revealed that event-related delta and theta oscillations play a specific functional role for the optimization of cognitive performance with both differentially contributing to different encoding strategies during the digit span-backward working memory task. Namely, delta responses evoked by items in each series matched the 'serial position curve', with higher delta power being present during the first and last items as compared to items presented in the middle of a series. Theta responses, in contrast, rather resembled a neural correlate of a chunking pattern. This EEG study contributed to our understanding of the neural oscillatory mechanisms underlying multiple item encoding, directly informing recent efforts towards memory enhancement through targeted oscillation-based neuromodulation. In a next step, we then used tACS to experimentally modulate these oscillatory activities and assess the induced effect on brain oscillations and memory performance. We could show that theta tACS applied at the individual peak frequency of theta (ITF) most effectively modulated spontaneous oscillatory theta activity but had not measurable effect on memory performance. In contrast, tACS stimulation applied slightly below this individual peak theta frequency showed to be better capable to improve memory performance. Importantly, this beneficial cognitive effect of tACS applied at a slightly lower frequency than ITF was observed to persist even after stimulation and was associated with tACS-induced changes in EEG frontal-parietal connectivity. Finally, in a clinical study on patients suffering from Parkinson's Disease with mild cognitive impairment (PD-MCI), impaired anterior-posterior functional connectivity caused by abnormal EEG delta-theta oscillations was revealed during a visual oddball task. Collectively, these studies highlight the importance of delta-theta oscillations for cognitive processing in the domain of memory, and demonstrate that these oscillations can be effectively modulated using tACS leading to measurable cognitive enhancements that persisted even after tACS stimulation was discontinued (tACS cognitive after effects). We also revealed

pathologically altered functional connectivity patterns within theta-delta oscillations to be associated with cognitive impairment in PD-MCI patients. The results of this thesis may therefore pave the way for developing new neuromodulation-based treatment approaches for improving cognitive deficits in patients suffering from disorders with underlying oscillatory deterioration patterns.