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# Training of self-regulation and ist effects on inhibitory control in children with ADHD

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Inhibitory control is a core deficit in Attention-Deficit/Hyperactivity Disorder that has been extensively investigated in both electrophysiological as well as neuroimaging studies. In healthy subjects, it has been most consistently linked to activation of the anterior insula and inferior frontal cortex, often also the anterior cingulate cortex, while electrophysiological work has reported increased NoGo N2 and NoGo P3 amplitudes compared to Go conditions. Further, the deficit of inhibitory control in patients affected by Attention-Deficit/Hyperactivity Disorder has been related to hypoactivation of these attention-related brain regions as well as a consistent reduction of NoGo P3 and some evidence for reduced NoGo N2 amplitudes.

As the temporal aspects of inhibitory control remain largely unknown to date, the first study used simultaneous electroencephalography and functional magnetic resonance imaging to provide insight into the sequential dynamics of this construct. To this end, 23 healthy young adults (mean age 24.4 years) performed a combined Flanker/NoGo task during simultaneous electrophysiological and hemodynamic recording. Separate analysis for both modalities yielded higher activation in the anterior insula, inferior frontal gyrus and anterior cingulate as well as increased NoGo N2 and NoGo P3 amplitudes in accordance with the literature. Combined analysis modelling sequential N2 and P3 effects through joint parametric modulation revealed correlation of higher N2 amplitude with deactivation in parts of the default mode network and the cingulate motor area as well as correlation of higher central P3 amplitude with activation of the left anterior insula, inferior frontal gyrus and posterior cingulate. Thus, the combined results suggest a general role for allocation of attentional resources and motor inhibition for N2 and link memory recollection and internal reflection to P3 amplitude, in addition to previously described response inhibition as reflected by the anterior insula.

Based on the extensive knowledge about inhibitory control deficits in children with Attention-Deficit/Hyperactivity Disorder, the second study employed functional magnetic resonance imaging to investigate neurofeedback treatment effects. Within a randomized controlled design, 16 children with Attention-Deficit/Hyperactivity Disorder (mean age 11.81 years) were randomly assigned to either neurofeedback or an active biofeedback control group (electromyogram feedback). All children received 20 sessions of training and performed a combined Flanker/NoGo task during functional magnetic resonance imaging before and after treatment. After treatment, children that received neurofeedback showed reduced symptom scores as well as increased activation in brain regions associated with inhibitory control, while children in the control group showed no symptom improvement and no changes in brain activation. Further, those subjects that successfully learned to apply training strategies, irrespective of the type of training, showed increased activation in an extensive inhibitory network, highlighting the importance of successful learning. This study was the first to investigate treatment and learning effects on the level of regional brain activation and provided valuable insight into the neurophysiological effects of this nonpharmacological treatment option.

Both studies present valuable and novel findings that add to the understanding of inhibitory control processes and suggest a positive effect of neurofeedback on deficits in this domain. However, validation in larger samples is needed.