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Neurofeedback-training of slow cortical potentials in children with ADHD: Part 1: evaluation of behavioural data

M. Straub, M. Döhnert, D. Brandeis, R. Drechsler

Department of Child and Adolescent Psychiatry, University of Zurich, Zurich, Switzerland

Objective: The aim of the study was to evaluate a training of the slow cortical potentials in children with Attention Deficit/Hyperactivity Disorder (ADHD). *Participants*: Children with ADHD aged 9–12 years participated in the study. *Method*: The training procedure consisted of 30 training sessions with Goefi, a neurofeedback system developed for children with ADHD. *Results*: Deactivation of cortical activity was slightly better learned than activation, as well in feedback as in transfer conditions. According to parents ratings, hyperactivity and impulsivity significantly improved after the training. However, behavioural changes were not or only moderately related to training performances. Teachers reported some improvement in the domain of attention, but there was no significant correlation between improvements and training performances. *Conclusion*: Although parents and children considered the training to be effective and beneficial, it remains unclear to which extent the improvements can be attributed to the neurofeedback or rather to unspecific treatment effects.

Neurofeedback treatment of children suffering from ADHD Part 2: EEG changes

M. Döhnert, M. Straub, U. Müller, E. Schulz, T. Padovani, H.C. Steinhausen, D. Brandeis, R. Drechsler

Department of Child and Adolescent Psychiatry, University of Zurich, Zurich, Switzerland

We investigated differences in quantitative EEG before and after treatment of children suffering from ADHD. Children ($N = 26$; age: 11.1 ± 1.15 years) diagnosed having ADHD were divided into two groups: one group was treated by neurofeedback ($N = 14$; training of slow cortical potentials), while the control group ($N = 12$) was treated by group therapy. Quantitative EEG measures were acquired during an eyes closed resting condition before and after the treatment. The average referenced EEG was Fourier-transformed to provide absolute power estimates for the delta, theta, alpha and beta bands. Analyses of subgroups (good vs. poor performer) were performed. For the neurofeedback group, treatment effects indicated slightly reduced central and occipital EEG theta in the post-measurement and increased power of alpha activity. Since children with ADHD are known to show increased theta activity, the results support the hypothesis that neurofeedback normalizes brain function

as measurable with EEG mapping. These results seem to be not specific to neurofeedback training, because the analyses of subgroups revealed inconsistent results. The increase of alpha activity is probably associated with well learned deactivation.

ADHD—subtypes in adults

A. Müller, G. Candrian

Gehirn- und Trauma-Stiftung, Chur, Schweiz

Attention-deficit hyperactivity disorder (ADHD) is a clinically heterogeneous disorder that is associated with educational and psychologically caused stress within families and school, adverse academic and occupational outcomes, and tremendous financial costs for public health and social departments. Electroencephalography has been used both in research to describe and quantify the underlying neurophysiology of ADHD, as well as clinically in the diagnosis and treatment of ADHD. Recent advances made it possible to transform EEG activity into numerical values by computation of amplitude and power for specific frequency bands of activity. This approach is termed quantitative EEG (qEEG). QEEG as well as event related potentials (ERP) are sensitive indicators of brain dysfunction. The significance of ERPs in the context of attention disorders was reported. In a study of our laboratory, a cluster analysis identified five distinct qEEG subtypes in a sample of 120 children with a diagnosis of ADHD. These subtypes are found to be of considerable clinical relevance having different implications with respect to medication and treatment. Further, possibilities in the analysis of ERPs and the implications for therapy are discussed.

Neurofeedback of SCP-and theta/beta-protocols for children with ADHD? Follow-up results

S. Kaller[1], C. Klinger[1], U. Leins[2], U. Strehl[1]

[1]Institut für Medizinische Psychologie und Verhaltensneurobiologie, [2]Universitätsklinik für Psychiatrie und Psychotherapie, Universität Tübingen, Germany

This study aimed to investigate the stability of outcome after neurofeedback training in children with ADHD. Two different neurofeedback protocols were used. One group received feedback of the theta- and beta-activity and the other group received feedback of the slow cortical potentials (SCP). Each group comprised of 19 children with ADHD. The training program consisted of three phases with 10 sessions each for pre-/post-testing and a follow-up evaluation 6 months after the end of the training. DSM-IV rating scales for parents and teachers, and tests of intelligence and variables of attention were administered. In addition, children underwent three booster sessions at follow-up. Analysis of data showed, that both groups are able to voluntarily regulate cortical activity, with the extent of learned self-regulation depending on task and condition. Parents and teachers report significant behavioural and cognitive improvements. Both groups improve in intelligence and attention. For the first time it could be shown that clinical effects remain stable for at least 6 months after the end of training. Also improvement of behaviour and of cognitive variables is stable.

Neurofeedback and cognitive performance

M. Doppelmayr[1], T. Pecherstorfer[1], H. Nosko[1], A. Fink[2]

[1]University of Salzburg, Physiological Psychology, Austria, [2]Medical Park Loipl, Bischofswiesen, Austria

Based on the ideas of Klimesch et al. who have repeatedly demonstrated a close relationship of episodic and working memory with the EEG theta band, as well as the relation of upper alpha band to semantic long term memory, we assumed that a modification of these bands by means of neurofeedback training (NFT), might have a positive influence on the respective cognitive processes. Hanslmayr et al. (2005) were already able to demonstrate that alpha NFT is capable, of enhancing cognitive performance in a mental rotation task. These findings lead to the assumption, that alpha NFT might help in the rehabilitation process of stroke patients.

After signing an informed consent, 32 stroke patients participated voluntarily in this study. All subjects were treated according to the standard procedure of the clinic, however 15 patients additionally participated in a relaxation program, while 17 patients were trained to enhance alpha power at Pz, using NFT. Two interesting findings can be reported. First, NFT participants were, in fact, able to enhance alpha power. Second, everyday memory performance, as assessed by the Rivermead Behavioral Memory Test, was significantly increased in the NFT group, as compared to the relaxation group.

Neurofeedback treatment of attention disorders after traumatic brain injuries

A. Bratic, S. Orsillo, M. Esslen, L. Jäncke

Institute of Psychology, Neuropsychology, University of Zurich, Switzerland)

Two individual case studies were carried out to show that NFB can be an effective treatment for attention disorders following traumatic brain injury (TBI). Two approaches were applied: Slow Cortical Potentials (SCP) and Alpha-Power Training. Before and after the NFB-training periods, a 30-channel EEG was recorded and cognitive performance was measured with standard attention and memory tests. The subjective condition of each patient was observed during training period by questionnaires. In experiment 1, the patient was trained to control her SCP; in experiment 2, an Alpha-Power-Training based on a preceding quantitative EEG was assessed to reduce excessive posterior alpha (8–12 Hz). Experiment 1: Although the patient failed to successfully discriminate positive and negative SCP, she showed significantly better cognitive performance after NFB-training. In addition, a reduction of impairments like fatigue could be observed and confirmed by her EEG. Experiment 2: The patient was originally suffering form massive headache, which went along with severe cognitive impairments and excessive posterior alpha-activity. After 19 sessions of NFB-training, he successfully learned to reduce his alpha-activity, which was also demonstrated by EEG changes. Headaches decreased and his cognitive performance improved significantly.

Treatment of focal dystonia with neurofeedback: two case studies in professional musicians

L. Jäncke, P. Dermota, N. Näpfli, M. Esslen

Institute of Psychology, Neuropsychology, University of Zurich, Switzerland

Focal dystonia (FD) is characterized by painless muscle cramps and loss of coordination and control, which results in a severe impairment in professional musicians. It is assumed that FD is a dysfunction of the CNS with hyperactivation of sensorimotor cortex, reduced cortical inhibition, and enhanced pre-motor potentials such as the contingent negative variation (CNV). To investigate the effect of slow cortical potentials (SCP) neurofeedback on FD, we applied the method on two professional musicians, a guitar player (JS) and a flutist (FL). During several weeks they learned via neurofeedback to shift their SCP in negative and positive directions. Before and after the training, personality and FD-questionnaires were applied and 30-channel EEG was recorded, including CNV for JS. Both patients learned to influence their SCP, also when they play their instrument. Subjective suffering form FD reduced on a scale from 1–10 (FL: 8.5–2.5; JS: 10–4.5). Post-training CNV in JS was reduced in left and right hand by 36.4% and 25.3%, as compared to pre-training CNV. Negative personality traits were reduced in both patients.

Two approaches to fMRI neurofeedback: direct feedback of the hemodynamic of a brain region and classification based neurofeedback

M. Weygandt[1,2], C.R. Blecker[2], R. Stark[1,2], D. Vaitl[2]

[1]Abt. für Klin. und Physiol. Psych., Justus-Liebig-Universität Giessen, [2]Bender Institute of Neuroimaging, Giessen, Germany

In recent fMRI Neurofeedback studies direct feedback of the hemodynamic of well-defined brain regions was investigated. In this context we examined whether subjects can learn to voluntarily activate or deactivate anterior cingulate cortex (ACC). An alternative approach may be classification based Neurofeedback. In this case no direct feedback of hemodynamic takes place but a classification algorithm learns to distinguish between patterns of hemodynamic corresponding to different experimental conditions. The classification decisions may be fed back. Here we investigated the feasibility of real-time classification of fMRI activation-patterns evoked by pictures of emotional content. *ACC-Neurofeedback*: Eight subjects participated in a neurofeedback training session of the activity of ACC. Average activation was fed back every 2.5 s. Subjects had to increase and decrease activity in corresponding conditions. *Real-Time Classification*: Erotic, disgusting, fear-related and neutral pictures were shown to 12 subjects. Activation-patterns belonging to single fMRI volumes were classified. Several parameters among others preprocessing and determination of features relevant to classification were varied. ACC-Neurofeedback Activation was significantly higher in activation—than in deactivation—conditions (df = 1,7; $F = 5.46$; $P = 0.05$; ANOVA). *Real-Time Classification*: Within the most beneficial setting median classification accuracy was 56% ($P < 10$–24; binomial probability).

Feedback-regulated motor imagery in Brain–Computer Interface (BCI) applications

C. Neuper

Institut für Psychologie der Universität Graz, Graz, Austria

Brain–Computer Interface (BCI) systems transform signals originating from the human brain into commands that can control devices or applications. Therewith, BCIs allow control of computers or external devices with regulation of brain activity only. The Graz-BCI developed by Pfurtscheller and colleagues uses motor imagery and associated oscillatory EEG signals from the sensorimotor cortex for movement restoration in patients who have highly compromised motor functions. This is based on the ground that motor imagery, specifically when creating kinesthetic feelings, can be used to produce movement-specific and locally restricted patterns of the oscillatory brain activity (i.e., quantified as event-related desynchronization/synchronization, ERD/ERS). It has been shown that it is possible to detect the imagery-related changes in ongoing non-averaged EEG recordings in real-time. This provides the possibility to use BCI technology also for neurofeedback applications. In this direction BCIs based on sensorimotor rhythms (SMR) control may contribute to enhance functional recovery and rehabilitation in patients suffering from chronic stroke. The main goal is to stimulate cortical reorganization and compensatory activation of non-lesioned brain regions and reduction of contralesional hemispheric inhibition through e.g., feedback-regulated motor imagery involving the paralyzed limb.

EEG- and MEG-source analysis for tactile and acoustic stimulation

C. Berger[1], U. Baumgärtner[1], K. Hoechstetter[3], M. Scherg[3], P. Stoeter[2], R.-D. Treede[1]

[1]Institut für Physiologie und Pathophysiologie, [2]Institut für Neuroradiologie, Johannes Gutenberg Universität Mainz, Germany

Dipole source analysis is a method to locate cortical generators. A direct comparison between EEG and MEG source analysis of evoked responses under the same conditions has not been performed yet. To obtain activation in two separate lobes, the somatosensory and auditory cortices of 16 subjects were activated by pneumatic stimulation of the left and right index fingertip and by binaural acoustic stimulation. Signals were recorded using a 61-channel EEG and a 122-channel-MEG simultaneously, and dipole source analysis was performed using BESA. Somatosensory activation in S1 and S2 resulted in almost identical dipole locations for EEG and MEG analysis (mean difference 2 mm), however, dipoles in S1 were found to be asymmetric in EEG analysis (further medial in the right hemisphere). The acoustic N19 was localized within A1; EEG sources were found to be 9 mm deeper than MEG sources. An advantage of either method not be concluded, although the standard deviation was lower in MEG. Asymmetric localization within S1 was probably not detected with MEG due to radial components. Deeper localization of EEG sources near A1 could be due to unfavourable volume conduction in lower parts of the skull or to higher sensitivity for week signals in MEG. Supported by DFG Tr 236/13-3

An investigation into the influence of back projections in the human visual system, on the stimulus related processing in striate cortex, using the evoked potential

V.L. Marcar, M. Esslen, L. Jäncke

Universitaet Zuerich, Abt. Neuropsychologie, Zuerich, Switzerland

We investigated the link between brain activity induced in the visual cortex and the evoked potential in 42 healthy adults by recording the EEG to a reversing windmill stimulus, a reversing, filled chequerboard and a reversing chequerboard with line drawn elements. We determined amplitudes of four components (N1, P1, N2, P2). VEP to the line drawn chequerboard lacked a N1 and P1 component observed with the other two stimuli. N1 from windmill and the filled chequerboard were identical. P1 differed between all stimuli. N2 and P2 differed between the windmill and the filled chequerboard, but were identical between the two chequerboard displays. We concluded that the N1 reflected the bottom-up activation of striate cortex, while the N2 and P2 were driven by a top-down activation of striate cortex. The N1 reflected the information in the low, while that of the N2 and P2 reflected the information in the high spatial frequency band. We also calculated the spatial frequency spectrum of the stimuli and the frequency spectra of EEG data. During the time period of the N1 and P1 we noted an increase in beta activity, while during the N2 and P2 theta activity increased. Beta activity appears to be linked to the bottom-up while theta activity appears to be linked to the top-down activation of striate cortex.

The effect of retinal stimulus location and stimulation frequency on visual evoked potential topography

W. Skrandies

Institute of Physiology, Justus-Liebig University, Giessen, Germany

The activity of cortical neurons is influenced by stimulus location and temporal modulation. We investigated how reversal frequency of black-and-white checkerboard patterns presented in different parts of the visual field affects evoked potential topography.

VEPs were recorded from an array of 16 electrodes over the occipital cortex in 12 healthy adults. A checkerboard reversal stimulus was presented with frequencies between 1.95 rev/s and 7.81 rev/s in the center or in the left or right visual field.

Evoked potential fields displayed the well-known components of pattern reversal evoked activity. Computation of FFT and wavelets displayed brain responses directly related to stimulation frequency. Further analysis showed that both retinal stimulus location and stimulation frequency affected VEPs. Field strength as well as topography changed significantly with different reversal frequency, and the pattern of lateralization of components depended on frequency (positive centroids: $F(4,44) = 3.41$, $P < 0.02$; negative centroids: $F(4,44) = 4.91$, $P < 0.005$).

Electrical brain activity elicited by visual stimuli shows globally similar features modulated by stimulus location and frequency. Our results indicate that different neuronal assemblies are activated by stimuli of different temporal characteristic.

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Brainstem dysfunctions in injuries to the craniospinal junction verificated via evoked potentials

P. Christophis, D. Wachter, U. Nestler

Neurochirurgische Universitätsklinik, Uni-Klinikum Giessen Marburg GmbH, Giessen, Germany

Injuries to the cranio-spinal junction and the upper cervical spine can cause irritation or damage of the brainstem. Twenty-six patients were investigated using acoustic (BAEP), visual (f-VEP) and somatosensory evoked potentials (MSEP and TSEP). BAEP was altered in 22 patients. In eight cases BAEP was changed unilateral. In another three cases BAEP was absent. MSEP was pathological in 23 cases. N20 signal was absent in six cases. N20 was changed more often than the N14. TSEP was marked pathological in 21 cases. P40 was slight changed in five and absent in seven cases. P40 was changed more extensively than the N30 signal. VEP changes were found in 24 patients. In three cases P100 was absent bilaterally. In the other cases P100 was marked or severe changed. The frequency and the constellation of the findings, as well as the character of the potential changes allow the conclusion that an injury at the cranio-spinal junction is able to cause irritations or damages of the brainstem, which are verifiable by EP.

Psychophysical and neurophysiological correlates of pain perception in patients with major depression

N. Trautmann[1,2], N. Hausenblas[2], U. Baumgärtner[1], G. Bleichhardt[2], R.-D. Treede[1]

[1]Institut für Physiologie und Pathophysiologie, [2]Abteilung Klinische Psychologie und Psychotherapie, Universität Mainz, Germany

It has been suggested that pain perception is reduced with major depression. This could be due to different processing of the sensory-discriminative, the affective pain component, or both. We investigated the sensory-discriminative pain component with psychophysical and electrophysiological methods in 12 patients with major depression and 15 age-matched healthy controls. Painful laser stimuli were applied to the dorsum of the right hand in 12 blocks of 20 stimuli. In alternating order, subjects had to (1) perform an intensity discrimination task or (2) where distracted by mental arithmetic. After each block, subjects had to rate pain intensity (VAS) and task performance was determined.

Patients and controls did not differ in VAS ratings, discrimination performance, arithmetic performance or laser evoked potential (LEP) amplitudes. Both groups exhibited task-related modulation of LEP amplitudes ($F = 5.4$, $P = 0.029$) as well as habituation across repetitive blocks ($F = 4.4$, $P = 0.001$).

These data show that the sensory-discriminative component of nociception as well as habituation is unaltered in patients with major depression.

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A gene-associated ''cognitive'' compensatory mechanism in preclinical Huntington's disease

C. Beste[1,2], C. Saft[2], J. Andrich[2], M. Falkenstein[1], V. Kolev[3]

[1]Leibniz Research Center for Working Environment and Human Factors, Dortmund, [2]Department of Neurology, Ruhr-University Bochum, Germany, [3]Institute of Physiology, Bulgarian Academy of Science, Sofia, Bulgaria

Error-processing is assumed to be dependent on the basal ganglia and the dopamine system. We assessed error-processing by means of the Ne/ERN in presymptomatic Huntington's Disease (pHD), a neurogenetic disorder and healthy controls. Even at the stage of pHD striatal degeneration and dopaminergic dysfunction appears, but without motor symptoms. On the other hand, research indicates that this stage may also be characterized by neurophysiologically mediated compensatory mechanisms. Wavelet-analyses reveal that the Ne/ERN consists of two components: a cognitive (delta-band) and a motor component (theta-band). In our study the Ne/ERN-grand averages did not differ between the groups. Subsequently we conducted a wavelet-analysis to account for possible frequency-dependent changes. Here it is demonstrated that the pHD group showed an increase in wavelet-power in the delta- and theta-frequency-band. Moreover, this increase was related to the underlying genetic alteration (CAG-repeat expansion) and the estimated age of onset indicating that point in time, when the disorder becomes symptomatic. The results suggest for a genetically mediated mechanism possibly compensating for degenerative processes on a functional level. Furthermore, they suggest for a new interpretation of mechanisms that might mediate the turnover from pre- to symptomatic stage of disease.

Sounding thoughts

T. Koenig[1], O. Brodwolf[2], O. Friedli[2], D. Weissberg[2], T. Dierks[1], F. Dombois[2]

[1]Department of Psychiatric Neurophysiology, University Hospital of Psychiatry, Bern, Switzerland, [2]Berne University of the Arts, Switzerland

EEG is traditionally displayed visually because writing continuous traces on paper was for a long time the only way to store the signal. Some features of EEG may however be better understood in the auditory domain: EEG typically involves oscillations, these oscillations may overlap; events may repeat, occur synchronously or follow each other with some delay or show complex, but systematic dynamics over time. Such features are typically much better identified by the ear than the eye. The aim of the presented project was to develop the hard- and software for the auditory display of multi-channel EEG data that represents the data in both esthetically and scientifically sound form. We will present sound examples of EEG data recorded from healthy and ill subjects using both audification (the signals are directly converted into sound waves and displayed on an accelerated timescale) and FM synthesis, where the signal changes the pitch and timbre of sounds. By displaying up to 22 channels, their interrelations and differences become auditable.

Semantic sentence processing and second language proficiency: a longitudinal ERP study

C. Hug[1], M. Stein[1], D. Brandeis[2], W. Strik[1], T. Dierks[1], T. Koenig[1]

[1]Department of Psychiatric Neurophysiology, University Hospital of Psychiatry, Bern, [2]Brain Mapping Research, Department of Child and Adolescent Psychiatry, University of Zurich

The N400 has been investigated in a number of cross-sectional studies on second language processing. In our longitudinal study we investigate ERP changes accompanying increasing language proficiency in second language learners at an earlier and later stage of second language acquisition.

Seventy-four channel ERPs to German sentences with congruent or incongruent endings were recorded from 16 English speaking exchange students learning German in Switzerland at the beginning of their stay (day 1) and after 5 months (day 2). Signal strength, computed as global field power (GFP), as well as topography of ERP difference maps (incongruent minus congruent) were compared between days.

The N400 effect, consisting of the well-known widespread centro-parietal negativity, was more pronounced on day 2 as shown by GFP-differences in the time window 416–456 ms. TANOVAs revealed topographical differences between day 1 and 2 in the time window 576–636 ms which were due to an altered processing of the correct sentences showing a lower GFP and an altered topography on day 2 as compared to day 1.

Our study shows that quantitative (different levels of engagement of neuronal structures) as well as qualitative changes (involvement of partially different neuronal

structures) in semantic processing accompany an increase in second language proficiency.

The generation of syntactic structures: insights from EEG time-frequency analyses

D. Roehm[1], H. Haider[2]

[1]MPI for Human Cognitive and Brain Sciences Leipzig, Germany, [2]Department of Linguistics & Center of Neurocognitive Research, University of Salzburg, Austria

In the present EEG experiment we investigated the generation of minimal syntactic structures. Participants were asked to produce verb-second (V2) sentences on the basis of sequentially presented NP-NP-Verb chunks 'pizza'/'bachelor'/'to order'. Visual cues either forced the sentence to be spelled out in past tense (i.e. with the finite verb in V2) or in the perfect (i.e. with a finite auxiliary in V2 and the main verb in sentence-final position). Verb-types differed with respect to whether they had an obligatorily separable particle ('to select') or not ('to order') and whether an additional prefix was added (e.g. 'preselect', 'preorder'). ERPs timelocked to the onset of the verb revealed a late positivity (550–800 ms) for double-prefixed particle verbs in comparison to the other conditions independent of verb position. In contrast, frequency analyses revealed significant differences between conditions in the alpha (reflecting verbal complexity) and beta frequency range (indicating the degree of grammaticality). Furthermore, phase coherence between electrodes revealed frequency-specific synchronization patterns reflecting long-range neural integration mechanisms during syntactic structure generation. The present results demonstrate that frequency-based analyses can overcome the methodological limitations of ERP acquisition during sentence production.

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G spectral power magnitude and topography in advanced meditators during different QiGong-meditations and resting

P.L. Faber[1], S. Tei[1,2], D. Lehmann[1], I. Shibata[3], G. Ohyama[4], T. Tsujiuchi[3], H. Kumano[2], A. Akabayashi[2], K. Kochi[1], L.R.R. Gianotti[1]

[1]The KEY Institute for Brain-Mind Research, University Hospital of Psychiatry, Zurich, Switzerland, [2]Department of Stress Science and Psychosomatic Medicine, [3]Department of Health Science and Social Welfare, Waseda University, Japan, [4]Department of Otorhinolaryngology, The University of Tokyo, Japan

What are the brain electric differences between QiGong meditation and no-task resting?

What are the differences between different QiGong meditations? Nineteen-channel EEG was recorded from eight experienced meditators of Master Feng-San Lee's group (Taiwan) during the following three meditations (10 min each): (#1) attention focus on breath counting, (#2) attention focus on 'thinking of nothing', (#3) doing slow-paced, respiration-synchronized arm movements ('Qi-Gong'). In addition, eyes-closed resting EEG (4 min each) was recorded before and after these three meditations. Both EEG spectral power in eight frequency bands and topography of the frequency band-wise power distribution on the head (i.e. the topographic gravity center location) were examined using exploratory statistics. Compared to resting, the meditations showed (a) decreased power (EEG theta, alpha1/2, and beta1/2/3 frequency bands, most pronounced in meditation #1), and (b) changed topography (anteriorized localization of EEG delta, theta, and alpha2 frequency bands, most pronounced in meditation #2). Localizations also distinguished between the three meditations. In sum, magnitude and topography of EEG spectral results clearly differed between QiGong meditations and resting as well as between the three QiGong meditations.

Differences between expert and novices in frontal midline theta during rifle shooting

T. Finkenzeller, G. Amesberger, M. Doppelmayr

Universität Salzburg IFFB Sport- und Bewegungswissenschaft, Abt. Sportpädagogik und Sportpsychologie, Hallein Rif, Universität Salzburg, Naturwissenschaftliche Fakultät, Abt. Physiologische Psychologie, Salzburg, Austria

A close relation of frontal midline theta has been reported to concentration (Nakashima and Sato 1993), as well as to emotional experience, to sustained (Kubota et al. 2001) and internalized attention (Aftanas and Golocheikine 2001; Park et al. 2002). During the pre-shot phase attentional processes are of upmost importance. Thus, it was assumed that experts will be able to focus better (Tremayne and Barry 2001) on the target. Accordingly a higher frontal midline theta should be observed.

Electroencephalographic activity during the pre-shot period was investigated in eight marksmen and 10 novices. EEG bandpower values have been calculated and a LORETA

analysis has been performed. Highest midline theta power was observed at Fz, followed by Cz and Pz with the smallest power located at Oz. Interestingly only at Fz experts exhibited a higher power as compared to novices. A comparison of Fz and frontal lateral electrodes revealed the highest theta power at Fz. Additionally, theta power increased continuously with time only at Fz and only for experts. LORETA yielded a significant difference between experts and novices at medial frontal and anterior cingulate areas. In the future, findings related to frontal midline theta might be used in neurofeedback training of marksmen.

Spectral power and Omega Dimensional Complexity of EEG during breath counting exercises in headache patients: a pilot study

L.R.R. Gianotti[1], S. Tei[2,1], P.L. Faber[1], Y. Eto[3], R. Yamamoto[3], T. Tsujiuchi[3], H. Kumano[2], K. Kochi[1], D. Lehmann[1]

[1]The KEY Institute for Brain-Mind Research, Psychiatrische Universitätsklinik, Zürich, Schweiz, [2]Department of Stress Science and Psychosomatic Medicine, The University of Tokyo, Japan, [3]Department of Health Science and Social Welfare, Waseda, Japan

In the resting EEG, headache patients show increased spectral power in slow EEG frequency bands compared to controls (e.g., T. Thomaides et al. 1996). Migraine patients also showed decreased Omega Dimensional Complexity (ODC) during attacks compared to attack-free times (H. Strenge et al. 2001). The exercise of breath counting (BC) reportedly reduces chronic pain (W.E. Mehling et al. 2005). We studied the effect of a single 4 min BC exercise on the EEG of 10 chronic headache patients (mean age 19.5 years, SD = 0.85; 9 women). Nineteen channel EEG was recorded on attack-free days with closed eyes during pre-resting, BC, and post-resting (4 min each). Subjects were told to silently count their inspirations during BC (from 1 to 10, continually repeating). Power spectral analysis and ODC analysis was done. BC compared to pre-resting showed a significant decreased of power in delta, theta, and alpha1. Moreover, post-resting compared to pre-resting showed a significant decrease of power in delta and theta. ODC significantly increased from pre resting to BC but showed no difference between pre- and post-resting. In sum, the results showed that a single short application of BC treatment in headache patients produced a change of the measured EEG parameters towards normalization, during as well as immediately after the treatment.

Model-based analysis of rapid event-related functional near-infrared spectroscopy (NIRS) data

M. Plichta, S. Heinzel, P. Pauli, A.J. Fallgatter

Laboratory for Psychophysiology and Functional Imaging Department of Psychiatry and Psychotherapy, University Hospital Wuerzburg, Germany

To validate the usefulness of a model-based analysis according to the general linear model (GLM) for the analysis of functional near infrared spectroscopy (fNIRS) data, a rapid event-related paradigm with an unpredictable stimulus sequence was applied to 15 healthy subjects. A parametric design was chosen wherein four different contrasts of a flickering checkerboard were presented. This design allows directed hypotheses about the rank order of the haemodynamic responses. Our results indicate the validity of amplitude estimation by three main findings (a) the GLM approach is able to identify activation in the visual cortex with inter-stimulus intervals of 4–9 s (6.5 s average) whereas in non-visual areas no activation was detectable; (b) the different contrasts lead to the hypothesized rank order of the GLM amplitude parameters: visual cortex activation evoked by highest contrast > moderate contrast > lowest contrast > no stimulation; (c) Analysis of null-events (no stimulation) did not produce significant activation in the visual cortex or in other areas.

We conclude that a model-based GLM approach delivers valid amplitude estimations and enables the analysis of rapid event-related fNIRS data, which is relevant in particular for cognitive studies.

The sound of emotion: an fNIRS study of the processing of emotional sounds

M.M. Plichta, A.B.M. Gerdes, G.W. Alpers, A.J. Fallgatter

Laboratory for Psychophysiology and Functional Imaging, Department of Psychiatry and Psychotherapy, University Hospital Wuerzburg, Germany

An enhanced neural processing of emotional pictures compared to neutral pictures has been documented in several studies. Evidence from fMRI and EEG paradigms supports the notion that the visual cortex is more activated when emotionally relevant pictures are presented. Startle and peripheral physiological data suggest that emotional sounds may similarly activate emotion circuits (Bradley and Lang 2000). However, there are no studies

on hemodynamic changes in the auditory cortex when emotional sounds are processed in primary auditory areas.

Therefore, we presented 18 positive, negative and neutral sounds of the International Affective Digitized Sound System (IADS) to 10 healthy subjects and recorded evoked brain activation with near-infrared-spectroscopy (NIRS).

Our results show that emotional sounds elicited stronger auditory cortex activation than neutral sounds. Comparing positive and negative sounds, no differences were found regarding the amplitudes of the activation, but the latencies were shorter in response to negative sounds.

This suggests that the enhanced processing of emotional information does not only take place in visual areas but can also be observed within the auditory cortex.

Effects of chromatic Ganzfeld stimulation on the brain's electrical activity

P. Pütz, J. Wackermann

Department of Empirical and Analytical Psychophysics, Institute for Frontier Areas of Psychology and Mental Health, Freiburg i.Br., Germany

The reported study explored effects of perception of homogeneous visual fields (Ganzfeld) of different colours on the brain's electrical activity. Twelve subjects were watching a uniform bright field in the interior of semitranslucent eyeshields, illuminated by a computer-controlled colour-calibrated projector (JVC DLA-G10), while listening to a monotonous sound via headphones. EEG was recorded from 19 scalp electrodes. Four different stimuli—three primary colours, red (R: $x = 0.655$; $y = 0.337$), green (G: $x = 0.285$; $y = 0.657$), blue (B: $x = 0.149$; $y = 0.054$), and white (W: $x = 0.309$; $y = 0.328$) as a control condition were presented in four 15-min periods, in a permuted order. Fourier spectra were calculated from artifact-free two-seconds EEG epochs and log-power differences evaluated for the colour conditions (R, G, B) versus the achromatic stimulus (W). Relative alpha1 (8–10 Hz) band power decrease and alpha2 band (10–12 Hz) power increase were found in conditions R and B, indicating an acceleration of alpha activity, mostly in the occipito-parietal region; while only general suppression of alpha power was observed in condition G.

Increased attention in healthy adults through neurofeedback

S. Rainer, B. Camenisch, M. Esslen, L. Jäncke

Lehrstuhl Neuropsychologie, Universität Zürich, Zürich, Schweiz

Recent publications confirmed that low-beta and SCP neurofeedback influence the neurophysiologic correlates of attention and thus have a positive effect on attention performance (Egner und Gruzelier, 2004, 2001; Fuchs et al. 2003; Heinrich et al. 2003; Monastra et al. 2002; Strehl 2004; Vernon 2002). The current study tested three different types of biofeedback with respect to their influence on attention in healthy, right-handed adults: a temperature biofeedback (raising temperature at right index; control condition), low-beta neurofeedback (increasing 12–15 Hz power in total frequency power spectrum), and slow cortical potentials (SCP) neurofeedback (shifting SCP amplitudes in the range of 0–2 Hz). Participants were equally assigned to three groups not knowing to which one of the three conditions they would belong, and were instructed to influence the visual feedback signal on a computer screen during 10 training sessions total. Before and after the full training, an extended test-battery for attention and a 30-channel EEG were applied to each participant. No significant results were found comparing the three conditions in any of the subtests of attention processing, nor in the EEG frequency band analysis. It is assumed that 10 training sessions are not sufficient for stable changes in attention processing under biofeedback training.

Impulsivity and compulsivity in patients with obsessive–compulsive disorder and borderline personality disorder: evidence for an electrophysiological continuum

M. Ruchsow, L. Hermle

Fachkrankenhaus Christophsbad, Göppingen, Germany

In the present study we investigated the error-related negativity (ERN) or error negativity (Ne) in 12 patients with borderline personality disorder (BPD) and a matched group of 11 patients with obsessive–compulsive disorder (OCD). The ERN/Ne reflects error monitoring processes and has its electrophysiological origins in the areas of anterior cingulate cortex (ACC) and prefrontal cortex (PFC) (1, 2), brain regions which are involved in the pathogenesis of OCD and BPD. Previous studies showed that impulsive patients with attention-deficit hyperactivity disorder and BPD have smaller (less negative) ERN/Ne amplitudes than compulsive patients with Gilles de la tourette syndrome and OCD (3–6). Subjects participated in a Go/Nogo task while a 64-channel EEG was recorded. Three ERP components were of special interest: The ERN/Ne and the early error positivity (Pe) reflecting automatic error processing and the late Pe which is thought to mirror the awareness of erroneous

responses. We found less negative ERN/Ne amplitudes in the BPD group compared to the OCD group. With regard to early and late Pe there were no group differences. This result is further evidence for the concept of an impulsivity-compulsivity spectrum, which has to be corroborated by future ERP studies.

Impulsivity and compulsivity in healthy controls: evidence for an electrophysiological continuum

M. Ruchsow, L. Hermle

Fachkrankenhaus Christophsbad, Göppingen, Germany

In the present study we investigated the error-related negativity (ERN) or error negativity (Ne) in a group of healthy controls. The ERN/Ne reflects error monitoring processes and has its electrophysiological origins in the areas of anterior cingulate cortex (ACC) and prefrontal cortex (PFC) (1, 2). Subjects participated in a Go/Nogo task while a 64-channel EEG was recorded. Three ERP components were of special interest: The ERN/Ne and the early error positivity (Pe) reflecting automatic error processing and the late Pe which is thought to mirror the awareness of erroneous responses. Dependent on their reaction times (RT) the entire group ($n = 32$) was divided into a high impulsiveness [HI] subgroup ($n = 16$) with relatively shorter RTs and a low impulsiveness [LI] subgroup ($n = 16$) with relatively longer RTs. We found less negative ERN/Ne amplitudes in the HI group compared to the LI group. With regard to early and late Pe there were no group differences. This result is further evidence for the concept of an impulsivity–compulsivity spectrum in healthy controls which has to be corroborated by future ERP studies.

Alterations in prefrontal brain activity of alcohol dependent patients after withdrawal measured with fNIRS

M. Schecklmann, A.-C. Ehlis, M.M. Plichta, H.K. Boutter, F.G. Metzger, A.J. Fallgatter

Laboratory for Psychophysiology and Functional Imaging, Department of Psychiatry and Psychotherapy, University Hospital Wuerzburg, Germany

Only a few investigations of functional brain activity in alcohol dependent patients exists, despite prominent prefrontal deficits and alterations in anatomy, neurophysiology, and neuropsychology after long term alcohol consumption. We used functional near-infrared spectroscopy (fNIRS) to examine the concentration changes in oxygenated (O2Hb) and deoxygenated (HHb) haemoglobin between 17 right handed alcohol dependent patients after detoxification and 17 matched healthy controls during a verbal fluency task and control task. Alcohol dependent patients showed normal behavioural performance (number of produced words) and physiological activation patterns (increase of O2Hb and decrease of HHb) over frontotemporal regions during phonological and semantical verbal fluency. However, they differed from the healthy control subjects. The magnitude of oxygenation was diminished and the localization of the activation was more restricted to inferior frontal areas. Altered prefrontal functional brain activation during verbal fluency in alcohol dependent patients in a detoxified state may precede behavioural or cognitive alterations with a later onset.

Gender differences in alpha- and thetaband of the human EEG during encoding of spatial information

E. Staltner, J. Weidenhöfer, S. Zeppetzauer, M. Doppelmayr

FB Psychologie Univ. Salzburg, Austria

Encoding processes measured by event related desynchronization (ERD) are associated with changes in the thetaband, while retrieval processes from long-term-memory are related to upper alpha. Theta activation is pronounced in frontal and alpha activation in parietal regions.

To examine whether those differences are found during the encoding of spatial information, subjects learned how to play the PC rally simulation game (ColinMcRae®). Fifteen men and fifteen women in the age range from 19 years to 40 years participated in this experiment. While the participants played this game EEG was recorded. Subjects had to learn the spatial relation. The differences in encoding into short-term-memory between men and women have been analyzed by comparison the topographic distribution of band power and coherences. Gender differences were found primarily in the thetaband. Women exhibited higher bandpower in the theta-, lower alpha- and upper alpha band as compared to men. The higher power values in the thetaband of women is interpreted as a more pronounced activation of central executive functions. On the other hand, significantly less power in lower alpha in parietal areas of men represents a stronger activation of attention-specific processes. Additionally high coherence between frontal and parietal electrodes has been found referring to the activation of fronto-parietal networks.

Identification of a figure defined by multiple visual cues: an ERP study

S. Straube[1], M. Fahle[1,2]

[1]Brain Research Institute, Department of Human Neurobiology, University of Bremen, Bremen, Germany, [2]The Henry Wellcome Laboratories for Vision Sciences, Department of Optometry & Visual Science, City University, London, UK

Although we perceive objects as clearly separated entities, the separation often relies on multiple visual cues. It is still unclear how the visual system integrates individual cues and to what extent an additional cue serves to achieve better figure-ground segregation. In the present study we tested (1) how the perceptibility of a figure modulates the event-related potential (ERP) and (2) how cue combination influences the ERP. In a binary task subjects had to distinguish between two mirror-symmetrical figures. Identification of the figure was complicated by randomization of its position and orientation. Stimuli consisted of a matrix of Gabors, where the Gabor elements of the figure differed from the background either in orientation, spatial frequency, or both (cue combination). Three levels of difficulty were used in each condition. For the single cues these levels were derived from a psychometric function measured in preliminary tests. In general, a better perceptibility is reflected by an increased negativity influencing the posterior P2 and N2 components. The combination of cues further increased this negative response, even if the perceptibility of the figure was very high already in the single cue condition.

EEG related differences of long- and short-term memory processes during the performance of a visuospatial task

J. Weidenhöfer, E. Staltner, S. Zeppetzauer, M. Doppelmayr

Universität Salzburg FB Psychologie, Salzburg, Austria

To analyse EEG differences between ongoing long and short term memory processes in visuospatial tasks, we designed a study using a 3D computer rally game (Colin McRae®, 2005). Klimesch (1999) clearly demonstrated that EEG alpha and theta band represent different types of memory processes. During learning of a new task theta power increases in frontal brain regions, indicating episodic memory demands. In contrast, semantic memory processes are reflected by a decrease of upper alpha power in parietal areas. Thus, we suggested a significant increase in theta power during the encoding of new, spatial information and a decrease in the upper alpha band during the retrieval process from long-term memory. First our participants had to learn a specific part of the game at home and in a second part of the experiment, when EEG was recorded, they had to retrieve this information and, additionally, had to learn some more new sections. Analysis of the data revealed that the better a memory trace is established, as by the number of sessions, the more the memory processes changes from an episodic to a semantic (long-term) memory. Furthermore, the results indicated a more pronounced activation in the right hemisphere.

Simultaneous synchronized EEG and fMRI recording in epilepsy

D. Brandeis[1], K. Bucher[2], P. Halder[1], J. Kroell[2], E. Martin[2]

[1]Department of Child- and Adolescent Psychiatry, University of Zürich, Switzerland, [2]MR Research, University Children's Hospital, Zürich, Switzerland

Simultaneous EEG-fMRI recordings have developed considerably during the last few years. Topographic EEG recordings with 64 EEG channels have become feasible in most MR scanners, and through synchronisation of the measurement (Mandelkow et al. 2006, Neuroimage 32:1120–1126) also high gamma band EEG activity can be examined. We demonstrate how this increased bandwidth can be used for the most typical EEG-fMRI application, the simultaneous measurement of interictal EEG fields and their event-related BOLD correlates in epilepsy patients. First results indicate that while spike-wave related topographies are most prominent in the lower frequencies (delta to alpha bands), some feature may also extend into the high gamma range.

Omega complexity: effects of different normalization strategies

C. Allefeld, J. Wackermann

Institut für Grenzgebiete der Psychologie und Psychohygiene, Abteilung für Empirische und Analytische Psychophysik, Freiburg i.Br., Germany

''Omega complexity'' was introduced by Wackermann (1996, 1999) as part of a system of global EEG descriptors,

where it is defined using the normalized eigenvalues of the covariance matrix of multichannel EEG. Because of the normalization Omega is independent of the global variance of the data, which is captured via the descriptor Sigma. Another way to achieve independence is to define Omega based on the correlation matrix. This has been proposed by Pei et al. (2005) because in this form it is additionally independent of the distribution of variance over channels. We shed some light on the respective advantages of the two versions, starting from the statement that Omega is intended as an estimate of the number of relevant sources of the EEG. While theoretically complexity should be based on the covariance matrix, numerical simulations show a close dependency between the two versions of the measure. Since EEG data often show artifactual fluctuations in channel variances, some normalization is necessary. Our recommendation is to use covariance complexity as the descriptor on the level of epochs, but only after normalization of the data on the level of experimental blocks or whole recordings.

Testing the evoked model on basis of phase sorted data

R. Adler[1], W. Klimesch[1], P. Sauseng[1], S. Hanslmayr[2], W. Gruber[1]

[1]Department of Physiological Psychology, University Salzburg, Austria, [2]Department of Experimental Psychology, Regensburg University, Germany

Already early EEG studies investigated the influence of alpha phase on cognition and behaviour. But results have been ambiguous. We used a perceptual task to investigate the influence of alpha phase (during stimulus onset) on the generation of ERP components. A post-hoc analysis of alpha phase was performed and two conditions, subsets of trials with peaks (maximal positive amplitude values) and troughs (maximal negative amplitude values) at stimulus onset were compared. The results show that stimuli presented during peaks and troughs of the alpha phase differ with respect to the amplitude and latency of the P1 component. In order to test whether these differences can be explained by an evoked component that is added to ongoing alpha activity we performed the following test. We added the grand average P1 component to the amplitude of alpha that is predicted for the phase sorted data (within the latency window of the P1) for ongoing alpha without phase reset. Because we found that the predicted value is smaller than the actually measured component even if a decrease in alpha power is simulated we assume that evoked components cannot be explained by a superposition with ongoing background EEG activity.

Thalamus as pacemaker of synchronous alpha oscillations during resting EEG/fMRI

K. Jann[1], T. Dierks[1], C. Boesch[2], T. Koenig[1]

[1]Department of Psychiatric Neurophysiology, University Hospital of Psychiatry, Bern, Switzerland, [2]AMSM, Department of Clinical Research, University of Bern, Switzerland

Thalamus as the pacemaker of cortical alpha oscillations (8–12 Hz) during resting EEG has been under investigation during the last years. Animal studies using in vitro and in vivo investigations as well as computational simulation methods yielded results that indicate the central role of the thalamus for generating and modulating alpha activity. In the recent years human studies using combined EEG/fMRI measurements found positive correlations of the alpha power to the BOLD signal in the thalamus and negative correlations in the occipital cortex. However, the question remains how these results confirm the thalamic-pacemaker theory of alpha waves? One possible answer may give the concept of functional connectivity. Interacting brain areas are thought to be synchronized. Since multi-channel EEG often shows oscillations with similar phase across electrodes we focus in our study on phase locked oscillations across all channels.

We measured six healthy subjects in a 3T MR-scanner with simultaneous recording of 92–channel EEG.

We found that the more synchronized the EEG channels are, the higher correlated is the thalamus to the BOLD signal, indicating the thalamus as the pacemaker of synchronized alpha oscillations.

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Wavelets in neurophysiology

A. Klein, G. Kutyniok, T. Sauer, W. Skrandies

Justus-Liebig-Universität Gießen

Wavelets have become a more and more popular tool for signal and image processing and can also be applied successfully for the analysis of neurophysiological data. Due to the good time-frequency localization of wavelets, the well-known problems arising from applying the short-time Fourier transform to time-localized signals can be circumvented.

We introduce the two major concepts of wavelet analysis, namely, the continuous wavelet transform from

harmonic analysis and the discrete wavelet transform from signal processing and explain the application of these concepts to neurophysiological data, in particular, EEG measurements. To illustrate their performance in applications, we also point out how the associated transforms can be efficiently implemented in terms of the fast Fourier transform (FFT) and filter banks, respectively. In addition, we present a natural analog of coherence for the wavelet domain, which allows for the detection of transient coherent events even in the presence of noise whose amplitude significantly exceeds that of the signal.

All these applications are illustrated by practical numerical experiments.