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Source analysis, imaging or localization of EEG activity?

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What are our goals when trying to analyze electrical brain activity? The most common answers are to localize or image the brain activity associated with prominent scalp peaks or significant changes between conditions. The most reliable information, however, the temporal evolution of activities in the involved brain regions, is rarely considered for displaying results as opposed to fancy movies of brain images suggesting reality despite the 'ill-posed' inverse EEG problem.

Apart from focal epileptiform EEG discharges and some early sensory evoked components, unifocal brain activations rarely exist. Thus, single dipole or beamformer approaches are limited. Likewise, the so-called 'zero-localization' property of some distributed inverse 'solutions' breaks down when bilateral or multiple brain activities overlap substantially in time, a situation common to cognitve ERPs.

Are there ways out of this dilemma? Source waveforms based on multiple regional source models reliably estimate and separate the various contributions in contrast to distributed models that rescale at each time sample. However, prior knowledge is often required to identify the involved brain regions. This can be gained from functional anatomical data and prior distributed models narrowing in on the relevant brain regions. Inverse methods need to improve by comprising condition-related, temporal and anatomical constraints.

EEG and ECoG Source Reconstructions

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EEG recordings and source recontructions analyse the far-field of the underlying brain-activity. ECoG measurements record the near-field of the cortical activity. In order to perfom source reconstruction a volume conductor model of the human head is needed which can be derived from anatomical image data (MRI) and utilised by the Boundary Element Method (BEM). For EEG reconstuctions usually a three-shell model is used in contrast to ECoG-models where single shell approaches seem sufficient, due to the isolating carrier foil of the grid-electrodes and the low conductivity of the skull. As source models equivalent dipoles or cortically constrained current density models can be used. Due to the rather complex ECoG-potential distributions simple dipole models are often not adequate, but more realistic extended current densities are necessary to explain the measured data in this case.

In a case study data from EEG (42 electrodes) and implanted ECoG-electrodes (8×8 grid) of an epileptic patient are compared, and volume conductor and source models for data analysis are described. Realistically shaped volume conductor models are derived from T1-weighted MRI-data, the ECoG-eletrode positions are determined from co-registered CT image data. The EEG-measurements can be easily explained by a single radially oriented dipole source. The ECoG shows more complex potential and source current distributions. The low conductivity of the skull and the larger distance between electrodes and cortical sources in the EEG case act as a spatial low-pass filter,

leading to easier to interpret potential distributions on the scalp as compared to the complex ECoG near field measurements.

Improved EEG/MEG forward modeling using conductivity fitting in realistic finite element volume conductor models

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Bioelectric source localization in the human brain from scalp Electro- (EEG) and Magnetoencephalography (MEG) signals is sensitive to geometry and conductivity properties of the different head tissues. A mathematical dipole is widely used as the model of the primary current source. All inverse methods are based on solutions to the corresponding forward problem, i.e., the simulation of the electric potential and the magnetic flux at the head surface for a dipole in the cortex sheet of the human brain. The electric conductivities of the head tissues vary across individuals and within the same individual due to variations in age, disease state and environmental factors. It is thus important to determine the conductivity parameters in individually shaped finite element (FE) volume conductor models and to appropriately model the dipole singularity to improve source analysis

We propose

(a) a Low Resolution Conductivity Estimation (LRCE) method using simulated annealing optimization on FE models that individually optimizes a realistically-shaped volume conductor with regard to the tissue conductivities. As input data, the method needs T1- and PD-weighted magnetic resonance images and somatosensory evoked potential (SEP) data. Simulation studies and applications to measured SEP data show that the LRCE method is able to simultaneously reconstruct the brain and the skull conductivity together with the underlying dipole source in somatosensory cortex and leads to an improved source analysis result.
(b) an improved subtraction approach to model the dipole singularity in FE-based source analysis. We describe our implementation and validate the approach using high-resolution tetrahedra meshes in a multi-layer anisotropic sphere model. We compare the subtraction approach with direct techniques in a variety of method-specificly tuned FE meshes with regard to forward topography and magnitude errors and with regard to the resulting inverse localization errors.

Incorporation of functio-anatomical a priori knowledge into EEG source reconstruction

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We present a technique to incorporate a priori information about the spatial structure of brain activity into low resolution electromagnetic tomography (LORETA) [1]. The space of potential sources is subdivided into areas (patches), which are likely to be activated as a whole on the basis of functional or anatomical findings (patch-LORETA). The spatial smoothness operator is modified such that smoothness is only imposed between points of the same patch, but not across patch borders. By computer simulations, the method was compared to other techniques (standard minimum norm, standard LORETA and "Unary", where the activity within the patches is forced to be uniform) and evaluated with respect to its behaviour with correct as well as inaccurate a priori knowledge at different noise levels. If the a priori knowledge is correct, both patch-LORETA and Unary yield a clearly more accurate reconstruction. However, if the a priori information does not fit, patch-LORETA still yields an acceptable solution, though not better than with conventional methods, while Unary results in unacceptable biases. Patch-LORETA is therefore effective in using compatible a priori knowledge and at the same time robust against erroneous information.

1. Pascual-Marqui et al., *Int. J. Psychophysiol.* **18**, 49 (1994).

Attaining exact localization in low-resolution imaging of electric neuronal activity: some technical details

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Scalp electric potentials (EEG) and extracranial magnetic fields (MEG) are contingent to the impressed current

density unleashed by cortical pyramidal neurons undergoing postsynaptic processes. EEG/MEG neuroimaging consists of estimating the cortical current density. Due to the ill-posed nature of this inverse problem, existing solutions have suffered from low resolution and significant localization error. The method known as standardized low resolution brain electromagnetic tomography (sLORETA) achieved exact, zero error localization. However, sLORETA consists of standardized current density computations, and although based on an inverse solution, it only achieves exact localization after standardization. We will show that sLORETA is unbiased and attains exact localization even under non-ideal conditions, in the presence of simultaneous biological and measurement noise. A further advantage of sLORETA is demonstrated: if an a priori current density distribution is known and true, then again sLORETA is unbiased (zero localization error) even in the presence of biological and measurement noise. Finally, we report a novel 3D-distributed linear low-resolution tomographic solution that, for the first time, attains exact localization. Technical details of the method will be presented, together with an outline of the proof that the method has zero localization error, even under non-ideal, noisy conditions.

Electrical source neuroimaging and validation

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Methodological advances, increasing availability, and a continued interest in localization have turned statistical, distributed EEG/ERP based source analyses into a common addition to spatial EEG/ERP analysis. Such source analyses are now starting to replace scalp analyses and illustrations, and are treated with increasing confidence like fMRI-derived activation patterns.

The main arguments supporting this trend are that EEG based electrical Neuromaging is based on physiologically sensible constraints and has been validated sufficiently, using source modelling and comparison with intracranial or fMRI derived activation patterns. The main arguments against this trend is that validations are limited to simple cases, and that informed users are usually aware of important constraints, ambiguities and shortcomings of their source analyses.

This debate is illustrated using examples from combined EEG-fMRI studies including our own sequential and simultaneous studies. We conclude that electrical Neuroimaging with typical constraints is validated for a small subset of simple source configurations, but resolving many configurations of interest suffers from both constraints and ambiguities. The status of EEG/ERP source localization does not yet warrant replacing scalp based with source based analyses. Instead, systematic but cautious source localization, plus awareness of characteristic limitations and ambiguities should be promoted in the field.

Identifying mutual information transfer in the brain with differential-algebraic modeling: evidence for fast oscillatory coupling between cortical somatosensory areas 3b and 1

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Although the origin of the fast oscillatory activity in the 600 Hz band found in the primary sensory cortical areas after electrical peripheral nerve stimulation is not yet completely clear, this activity might provide a new non-invasive window to the brain, since it is most likely not caused by the EPSPs as the common low frequency activity. We investigate the coupling between the two spatially distinct components of the 600 Hz band activity in order to elucidate the possible information transfer.

Source localization based on simultaneously recorded electroencephalographic and magnetoencephalographic data revealed two dipolar sources in the primary somatosensory areas 3b and 1 for the 600 Hz band activity. The activation curves of both dipoles over time were modeled with the help of coupled differential-algebraic differential equations assuming a thalamic input signal.

We found evidence for a coupling indicating mutual information transfer between these two cortical areas, contradicting the assumed feed forward information transfer from area 3b to area 1.

The study adds further evidence to the hypothesized heterogeneous character of the high frequency oscillations. Differential-algebraic modeling with differential equations provides a general framework to investigate mutual information transfer in oscillatory brain activity.

The electric source reconstruction in the study of cortical motor control

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One of the central challenges facing many scientific disciplines is to understand how a voluntary human act is organized. This chapter gives an overview how this question was approached by us using source reconstruction techniques. One can follow how the advancement of recording (increasing the number of electrodes) and analysis (from equivalent dipole models to distributed source models) techniques have helped us to get a deeper insight into the understanding of the motor functions. Different applications will be discussed starting from organisation of a simple voluntary act in healthy subjects and in deafferented patients and going to the organisation of the most skilful performance—music playing and music imagining. The application of source reconstruction techniques in the investigation of involuntary movements (myoclonus) and in testing of hypothesis about the functional significance of movement-related cortical components will be given.

The cardioballistic artifact in EEG acquisition during functional magnetic resonance imaging

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Recently, the feasibility of EEG recordings during functional magnetic resonance imaging (fMRI) has been shown repeatedly. However, distortions by gradient and cardioballistic artifacts (CBA) have to be treated by artifact reduction methodology. Most frequently simple subtraction algorithms are used for that reason. Therefore, an average-template representing the entire set of artifact epochs is subtracted from each single artifact epoch. Since gradient artifacts are invariant because of their technical origin, they can be removed almost completely dependent on the accuracy of sampling. However, the application of such a method on cardioballistic artifacts turned out not to be sufficient. Cardioballistic processes are highly variable due to their biological origin. They seem to be overcorrected by template subtraction. Neither a heartbeat evoked potential (HEP), which usually can be seen in heart-beat locked EEG-activity, nor its corresponding topography can be found in the EEG after CBA-template subtraction treatment. Moreover, amplitudes of evoked potentials (EP) measured during fMRI usually are higher than if they were recorded outside an fMRI environment. The absence of this phenomenon in the averaging of HEPs measured during fMRI also indicates overcorrection by simple template-subtraction.

Wavelets forward and backwards

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Usually, the wavelet transform is used for signal analysis only, computing time-frequency components of the underlying to signal. Recall that the wavelet transform computes a redundant representation of a univariate, time dependent signal which depends on two parameters: time and scale, the latter one closely related to frequency. There are, however, applications that require also an inverse transformation, like the removal of artifact signals that can be located in time and frequency. The inverse transform is less simple and requires a higher computational effort since it also contains an averaging opertation. Moreover, the fact that not every bivariate function depending on time and scale is a wavelet transform of some function must also be taken into account. Nevertheless, also an inverse wavelet transform can be implemented efficiently and turned out to be a useful tool in an autocoherence-based approach to the removal of cardioballisitic artifacts.

Removing cardioballistic artifacts from the EEG with wavelet methods

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Removing cardioballistic artifacts (CBA) from the EEG is a complex problem, because

- the artifacts appear frequently, but not completely regularly,
- their form varies over time,
- they cannot be modelled reliably,
- and the contribution of CBA-components which are not phase-locked to the heartbeat is unknown.

We present a method that defines autocoherence for single EEG-channels via randomisation, and allows the removal of CBA-components with strict phase-locking to the heartbeat.

To achieve this, the wavelet-transform of the average artifact is masked with wavelet-autocoherence in order to mask out any components which are not phase-locked to the heartbeat, and to reduce noise. The result of the masking operation is subjected to the inverse wavelet transform, resulting in an artifact template for each contaminated EEG-channel.

The method resembles that of Allen et al., but it is much more restrictive in selecting artifact components. However, it only suppresses phase-locked components, making a slight under-correction likely, as opposed to Allen's method, for which we suspect a slight over-correction, because the latter forces the average of all contaminated periods to be zero.

Habituation of human heat pain and of brain evoked potentials: peripheral and central components

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Suppression of heat responses in primary nociceptive neurons when stimulated repeatedly was shown in animal models in vivo (fatigue of AP-discharges) and in vitro (tachyphylaxis of heat-induced currents). We now investigated whether heat pain in humans correspondingly display signs of habituation.

Heat pain and evoked potentials (EP) were elicited in 16 volunteers with a contact heat evoked potential stimulator (CHEPS). Three stimulus intensities were applied in random order (threshold, moderate and maximum available [51°C]) either to fixed or variable locations at the forearm. The CHEPS reliably induced heat pain (e.g., numeric rating scale [NRS, 0–100]: 33.9 ± 6.9 at maximum temperature, variable location) and heat-evoked potentials. Pain ratings and EP-amplitudes displayed significant temperature dependence and were reduced when heat pulses were applied repeatedly to the same skin area ($P < 0.005$, main effect, ANOVA) with the largest differences seen at the moderately noxious temperature (factor of 2). These task differences clearly depended upon fatigue in the condition fixed stimulation where ratings and EPs markedly decreased during the first stimuli and then remained approximately constant. In conclusion, human heat pain displays signs of habituation reflecting tachyphylaxis and fatigue of mainly peripheral nociceptive neurons.

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Pain inhibits pain: the effect of cold pressure test on pain perception and laser-evoked potentials

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Diffuse noxious inhibitory control describes the inhibition of pain by heterotopic noxious stimulation shown in electrophysiological studies in animal and man. We investigated the effect of a remote painful stimulus on pain perception, amplitudes and latencies of laser-evoked potentials (LEP) compared to the effect of a remote non-painful stimulus in 10 volunteers. For painful conditioning subject immersed the left hand in cold water (3°C) for 2 min whereas non-painful condition was immersion of the left hand in warm water (34°C) for 2 min. Each subject underwent both conditions on different days. LEP were recorded after stimulation of the right hand in 2 trials before and in 5 trials after immersion.

Following the cold pressor test, pain ratings were reduced by 63.0% and LEP amplitudes by 41.1%, wheras in the control condition ratings were reduced by 62.2% and LEP amplitudes by 29.2%. These results suggest that both DNIC and habituation reduce thermal pain perception and LEP.

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The impact of sleep deprivation on pain modulation: Psychophysical and neurophysiological correlates

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The experiment investigates the impact of sleep deprivation on cortical evoked potential correlates of central nociceptive processing.

Ten healthy subjects with good sleep quality (Pittsburg' Sleep Quality Index ≤ 5) were investigated twice, once after a night of habitual sleep and once after partial sleep deprivation. Laser heat pulses eliciting moderately painful pinprick sensations were used as experimental stimuli. Laser evoked potentials (LEPs) were recorded from

midline and lateral scalp positions. Attentional focus during the painful stimulation was systematically varied. Volunteers were challenged to either discriminate between different stimulus intensities (focussed condition) or to solve an arithmetic task (unfocused condition). As neutral condition subjects were not asked to do anything (unattended condition).

N2-P2 amplitudes (vertex response) depended on the attentional focus (distraction < unattended < attended) and were reduced after sleep deprivation (ANOVA, $P < 0.05$). The interaction between sleep condition and attentional focus was highly significant (ANOVA, $P < 0.01$); differences between attentional conditions were profound after habitual sleep, and hardly present after sleep deprivation.

These results show that attentional modulation of pain processing is impaired in sleep deprivation. The low level stable response could be due to impaired neural regeneration—like a "default mode" of the brain under the lack of sleep.

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Linear summation of stimulus properties in the VEP

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The components of the visual evoked potential represent different processing stages in the visual system. Their amplitude depends on the number of neurons processing the stimulus. The 'two component' theory proposed by Victor and Zemon (1985) attributes stimulus related activation to a luminance and a contrast mechanism, with the former preceding the latter. The evoked potential due to this mechanism has been linked the mean luminance, represented by the value of the function F(0) in the spatial frequency spectrum, of the stimulus. We measured the visual evoked potential (VEP) from electrode Oz in 23 healthy, adult volunteers to three contrast reversing displays, containing a 'Windmill', a 'Dartboard' and the root-mean-squared (RMS) version of the 'Dartboard'. The first two stimuli had identical mean luminance; the latter two stimuli had the identical pattern. The Windmill and the Dartboard displays evoked the identical amplitude in the N75 component. The two dartboard displays evoked the identical amplitude in the N135 and the P230 components. These findings support the division of visual processing into a luminance- and a contrast-based mechanism as advocated by the 'two-component' model proposed by Victor & Zemon.

Changes of Evoked Potentials and Brainstem Reflexes caused by Large Temporal Brain Tumors

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In 55 patients with temporal brain tumours the electrical (BR) and mechanical (GR) elicited blinking reflex, the jaw-reflex (MR) were derived as well, as the acoustic (BAEP) the somato-sensory (MSSEP) and the flash elicited visual (f-VEP) evoked potential. The infratentorial generated BR, GR and BAEP showed very frequently (>3/4 of the cases) slight pathological changes (pontine and ponto-bulbar). In contrast to this, the predominantly tentorial and supratentorial generated MR, cortical MSSEP and the f-VEP indeed showed less frequent but more marked signal changes than the BR, GR and BAEP. On grounds of the constellation of the electrophysiological findings is to assume, that the mass-shift of the brain lead very early to a slight infratentorial brainstem irritation due to an cranio-caudal brainstem displacement and later to a marked irritation of the tentorial and supratentorial signal generators, because for the present there is (supratentorial) more space for unhindered mass-displacement. After the space is occupied the immediateness of the tissue irritation lead to more intensive signal changes than those of the infratentorial generated electrophysiological signals. The last remain for the present unchanged.

Electrophysiological monitoring after resuscitation

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Forty-seven patients underwent electrophysiological examinations after resuscitation. Twenty-nine male and eighteen female with an average age of 56.6 years had been included. All patients underwent studies of BAEP, M-SSEP and flash-VEP. Twenty-three patients died, thirteen of them showed a loss of M-SSEP within 24 h after resuscitation, three a loss of M-SSEP on one cortical side, four clear cortical disorders in M-SSEP, one a discrete and another one a normal M-SSEP. BAEP showed a loss of pontine signal in five patients, a loss on one side in three patients, clear or severe pontine BAEP-disorders in three cases, discrete pontine disorders in seven cases and a normal BAEP in three cases. Two recordings could not be evaluated due to artefacts. Eleven patients showed a loss of flash-VEP, ten cases severe disorders of flash-VEP and

only two patients, who died, showed discrete disorders of flash-VEP. Four of the patients who survived showed a loss of cortical M-SSEP and a loss of flash-VEP. All of them were discharged from hospital in a vegetative status.

The patients, who survived resuscitation in a good clinical condition (n = 12) showed normal, discrete or moderate disorders of M-SSEP. Five had severe disorders in flush-VEP.

Multimodal brain mapping of impaired semantic processing in dyslexic children: developmental delay or deficit?

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Dyslexia is a specific disorder of reading acquisition with a high prevalence. Several studies have shown that semantic processing and sentence comprehension are impaired in dyslexics. We examined whether impaired semantic processing can be explained by developmental delay. We compared brain activity of dyslexic 5th graders with normally reading children in both 5th grade and in 2nd/3rd grade (reading-level matched) using a sentence reading task with EEG and fMRI.

The analyses focused on incongruency effects (incongruous vs. congruous endings) indicating semantic processing. In fMRI, dyslexic children showed a decreased incongruency effect in the left hemisphere, in supramarginal regions ($P < 0.001$) compared to the 5th grade controls and in middle temporal regions ($P < 0.001$) compared to reading-level matched controls.

In EEG, the incongruency effect in dyslexic children was reduced and topographically different ($P < 0.01$) at 380 ms (N400) compared to normal reading 5th graders, but did not differ from reading-level matched controls. However, at 535 ms the incongruency effect in dyslexic children was topographically different ($P < 0.05$) from reading-level matched controls, but did not differ from 5th grade controls.

Both EEG and fMRI results demonstrate that semantic processing in dyslexic children differs even from reading-level matched controls, suggesting a specific processing deficit rather than a developmental delay.

EEG Theta-synchronization indicates binding of face elements

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Higher order cognition integrates information across large-scale neurocognitive networks. This integration is assumingly achieved by synchronizing neural activity within the network (binding). In the present experiment, 13 subjects viewed continuously moving and rotating elements of a schematic face while 74 channel EEG was recorded. At certain instances, the configuration of the elements matched a face (T0). Artifact-free 1 s EEG epochs were selected at −/+ 500 ms around T0 and at time intervals remote from T0 (TRnd). The data was transformed into multichannel time-frequency domain using complex Gabor-functions. In each epoch the amount of zero phase-lag synchronization (Global Field Synchronization) and Global Field Power (GFP) was assessed as function of time and frequency. GFS and GFP values were averaged within each subject separately for both conditions. Conditions were compared using time and frequency wise paired *t*-tests In a time period around 450 ms before T0, increased synchronization in theta was observed, and around 100 before T0, gamma-band synchronization was increased. These increases of synchronization could not be accounted for by an increase of signal power, i.e. by additional generators and must therefore have been caused by a phase-locking of previously active generators representing the different face elements.

Alpha and theta brain oscillations underlie object selective attention processes

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Alpha-band oscillations have been associated with attentional processes (Ward, 2003; Worden, M.S. et al., 2000).

It is not yet fully understood which areas produce those attention-dependent oscillations. We applied a spatial attention task (Martinez et al., 1999, 2001) to 10 human subjects while their EEG was registered. Specifically, white squares were presented to either the left or right upper visual hemi-field. Subjects had to detect offsets of their corners while maintaining fixation on a central cross. An arrow indicated which corner they had to attend in each trial. To determine the spectral density of the neuronal activity (J. F. Gomez and R. W. Thatcher, 2001) we used the swLORETA method (Palmero et al., 2007). For this purpose an FFT was computed from 0 to 500 ms post stimuli. We obtained that both the attended and the unattended condition, provoked a power increase in the theta and in the alpha bands which was higher for the attended condition. In the theta band all conditions activated the inferior and medial frontal gyrus, and the superior temporal gyrus. In the alpha band the occipital lobe (BA 18) and the middle temporal lobe were activated. The activation of those areas was significantly higher for the attended targets. We concluded that both alpha and theta oscillations are enhanced during object selective attention and that a network of frontal, temporal and occipital areas support those oscillations.

Resemblance of EEG and MEG Topographies during Visual Stimulation in Range of Individual Alpha Frequencies

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Visual stimulation with flickering light can lead to alpha entrainment in EEG and MEG recordings (photic driving). We show that successful alpha entrainment leads to intra-individually similar topographies and, moreover, that the same non-linear oscillators underlie this entrainment. Topographies obtained by photic driving in range of the individual alpha frequency were analysed by means of adapted matching pursuit algorithms. Topographies in ranges close to the 0.5 and to the 1.0 multiples of individual alpha-frequencies yield high covariance values with the topographies of the 1.0 alpha-frequency. Furthermore we suppose that other topographies found around the 0.5 multiple of the individual alpha-frequency describe additional oscillators, which complement the non-linearly coupled system.

Deactivation of the medial prefrontal cortex in experienced Zen meditators

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Zazen meditation exercises the detachment from intentions, thoughts and emotions. Zen meditators claim that this detachment carries over into their daily lives. We expect to find changes in their brain activity compared to a group of non meditators during no-task eyes closed resting state.

58-channel EEG was recorded from 15 experienced (12.3 ± 5.6 years) Zen meditators and 15 non meditators. 20 s eyes open followed by 40 s eyes closed (4 cycles) was recorded and the eyes closed condition analyzed using frequency band-wise standardized Low Resolution Electromagnetic Tomography (sLORETA).

The voxel-wise comparisons of the resulting intracortical standardized current density values corrected for multiple testing revealed a significant difference in the inhibitory delta band. Zen meditators showed an increase of delta activity mostly in the medial prefrontal cortex (MPFC) and to a lesser extent in anterior limbic regions.

MPFC is known to be involved in the integration of emotional and cognitive processes. We interpret the increased delta activity in MPFC during resting in meditators as an inhibition in emotional and cognitive engagement that might reflect the higher detachment in everyday life described by Zen meditators. The present results point to a plasticity change of the brain activity following a longlasting Zazen practice.

Relation of phonological skills and early visual print processing in preschool children

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Poor phonologic skills are considered as the core deficit in dyslexia. This study aims to clarify how phonological

performance affects the visual N1 ($\sim$150–250 ms) as an index for print specificity when children learn to read (Maurer et al., 2005, 2006).

Print processing was investigated in preschoolers (age 6.4 $\pm$ 0.3 years) using event-related-potentials (64 channels) after a 6 week training of letter-sound associations. Symbols served as control condition.

Children (n = 37; 21f) were grouped in high (HP: $\geq$65-percentile, n = 18) and low (LP: $\leq$35-percentile, n = 13) performers according to their phonological performance. The groups were matched for age, IQ and gender but tended to differ in letter knowledge (HP > LP).

Analyses focused on the N1 mean amplitudes around the individual peaks ($\pm$20 ms) at electrode PO7. An ANCOVA with covariate "letter knowledge" revealed a significant interaction of condition and group ($P < 0.01$) pointing to specialization of the N1 to words in HP. Furthermore topographic N1 condition differences (TANOVA) were found in HP (160–261 ms; $P < 0.01$) only.

These results indicate that children with good phonological skills show early differences between processing words and symbols after a brief training. Longitudinal results after learning to read will show how phonological skills and initial N1 specialization contribute to prediction of reading difficulties.

Effects of a grapheme-phoneme training on visual and auditory word processing in preschool children: an ERP and fMRI study

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Learning related changes in visual (v) and auditory (a) word processing was investigated in preschoolers (age 6.4 $\pm$ 0.3 years) using ERP (64-channels) and fMRI (3T-GE) in a cross-over training design.

ERPs (n = 36)/fMRI (n = 19) of audiovisual word (W) and falsefont (FF) processing were recorded before and after a short ($\sim$6-weeks) computerized grapheme-phoneme training (GT) and a non-linguistic number training (NT). In addition, children's letter knowledge was tested. Analyses focussed on (i) improvements in letter knowledge, (ii) changes in word-specific (W-FF) topographies of early visual (vP1, vN1) and auditory (aP1, aP2) ERPs using TANOVAs and (iii) fMRI activity in the network for reading. As expected, children improved their letter knowledge more during GT than during NT ($P < 0.001$).

Changes in word-specific topography were found ($P < 0.05$) in the vN1 (222–262 ms) after GT only, reflected by a more pronounced bilateral negativity of the W-FF difference over the occipito-temporal scalp. Neither the preceding occipital positive vP1 (103–163 ms) nor the fronto-central positive aP1 (97–137 ms) or aP2 (158–218 ms) exhibited topographic training effects. Correspondingly, fMRI data revealed more pronounced activity to W than FF after GT only, in occipito-temporal areas in both hemispheres.

We conclude that the formation of the reading network starts with the specialisation of the occipito-temporal cortex to print when children learn grapheme-phoneme associations.

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Anisotropy in M/EEG Source Reconstruction Using the Finite Element Method

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Successful M/EEG source reconstruction requires fast and accurate computation models. Finite Element (FE) models enable the flexiblehandling of anisotropic volume conductivity. We study the influence of three dipole models (subtraction approach, SA, St. Venant principle, VP, and partial integration, PI) on the numerical accuracy within concentric multi-layer sphere geometries. More specifically, a 5-layer FE model (scalp, skull, CSF, grey and white matter) and a 7-layer FE model (plus an inner GM shell) are used with anisotropic conductivity tensors. For validation, we use well-known analytical series expansions in spherical harmonics available for this setting. Numerical errors are measured in terms of the Relative Error, RE. Extensive tests using several FE models show that SA cannot be recommended as dipole model in anisotropic cases. Instead, PI produces in general lower numerical errors than the other dipole models. These findings, however, depend strongly on the dipole position in the FE model: SA and PI minimise RE

when the source is at the barycentre of an element, while VP minimises RE when the source is at a mesh node. Nevertheless, PI as dipole model seems to be best for the anisotropy case with respect to numerical accuracy, computational amount, and memory requirement.

The influence of low blood alcohol concentrations on explicit memory: an ERP-study

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The objective of the study was to investigate the influence of low blood alcohol concentrations (0.030−0.040% im steady state) on explicit memory (picture recognition) using Event-Related Potentials (ERPs). The study design was a placebo-controlled single-blind cross over trial. Twelve healthy subjects participated in this picture recognition task of simple object drawings (repetition interval 3–4/10–20 Items). Under alcohol influence subjects made more mistakes recognising the 'old' pictures than the 'new' ones without this result correlating with the length of the repetition interval. This is a suggestion that alcohol inhibits explicit memory ('old' pictures) and not implicit memory ('new' pictures). We found under alcohol influence parietal a positive enhancement of the late components of the old/new effect, which indicated dysfunctional explicit recognition processes. These two results together can be linked to a specific oppression of ACh-dependent memory functions that are known to be depressed after the treatment with anticholinergic drugs.

Elimination of cardioballistic artefacts from EEG-data with methods of Wavelet analysis

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During simultaneous examinations of brain activity by electroencephalogramm (EEG) and magnetic resonance imaging (MRI) the electrodes of the EEG are situated in the magnetic field of the tomograph. Even if we assume optimal fixation of the proband, tiny movements caused by the heartbeats provoke induced currents, which are recognized by the electrodes and falsify the EEG.

The elimination of these cardioballistic artefacts cannot be accomplished with classic methods basing upon simple averaging and Fourier transformation, because the artefacts are lightly varying in time and shape. Furthermore due to lacking explanation it is not sure, to what extent the artefact is provoked by non-cardioballistic components. Our poster describes a numerical process to eliminate such artefacts with methods of Wavelet transformation and auto coherence.

After averaging all noised data intervals of a constant length around the heartbeats to an average artefact, we also create an auto coherence mask out of these noised intervals for masking the wavelet transform of the average artefact and eliminating all components of non-cardioballistic origin. Retransformation gives the cleaned artefact, which represents only cardioballistic noise. After all we obtain the cleaned signal of every EEG-channel by subtracting the related artefact from the noised data intervals.

Contributions to early VEP components

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The interpretation of EEG-data is still not solved to a satisfactory level. No controllable, systematic correlation for neuronal activity and EEG rcording has been found so far. Shawkat and Kriss (2000) have shown a corrlate of contrast variation and visual evoked potential (VEP) amplitude. Variation of the contrast results in different postsynaptic potentials and thus evokes changes in VEP amplitude. This work now aims to identify a new controllable correlate by neuronal recruitment. It appears that the postsynaptic activity as well as the neuronal recruitment affect the amplitude of the visual evoked potential (VEP). We investigate the VEP amplitude change as a result of contrast change and variation of the totel area affected by the contrast reversal (stimulated area), keeping the absolute size of the stimuli constant. The stimuli consist of concentric checkerboards with four different contrasts (<100%, 75%, 50%, 12.5%) and sizes of stimulated area (50%, 37.5%, 25%, 12.5%). Contrast change is expected to affect the postsynaptic activity, while the variation of the stimulated area is expected to affect the amount of activated neurons within the visual system. The results support this hypothesis. Variation of the totel area affected by the contrast reversal shows a linear correlation with the early VEP component N75.

Tracing Origin and Propagation Areas of Epileptic Activity by combining TMS and EEG source analysis

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Objective: To investigate the cortical responsiveness to Transcranial Magnetic Stimulation (TMS) by recording EEG responses in epileptic patients.

Methods: A 64 electrodes cap (10–20 system compliant) has been used for EEG recordings. TMS has been used to stimulate six symmetrical areas, C3/C4, F3/F4 and P3/P4. Thirty single cosine biphasic pulses (ISI = 5 s) at 80% of the maximum stimulator output (MSO) have been delivered by means of a figure-of-eight coil to each target area. Latency and amplitude of event related potentials (ERPs), distribution and dipole source analysis of the signals recorded following the stimulus have been analyzed. Two patients with focal epilepsy and four healthy volunteers have been measured.

Results: In control subjects it has been possible to reproduce the results shown in literature (P30, N45, N100 targeting the primary motor area) and to obtain reliable answers from the other stimulated areas. In both patients the ERPs differed in terms of distribution and shape. An abnormal high 54 μV negative peak at 103 ms over the left frontal electrodes when stimulating left M1 and a circumscribed centro-temporal pronounced 45 ms wave have been obtained when stimulating over F3 and right M1 of the patients.

Conclusion: It appears to be possible to investigate abnormal connectivity between cortical areas in epileptic patients.

Topographic differences in phonological lexical processing between dyslexic and normal reading 5th graders: an ERP study

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Approximately 5–10% of the children are diagnosed with developmental dyslexia and exhibit severe reading problems.

This study examined differences in the visual ERPs between dyslexic and normal reading 5th-graders focusing on differences in processing words and other items varying in lexical, orthographic and non-orthographic respects.

The ERPs of dyslexic (n = 16, 11.6 ± 0.4 years) and control (n = 27, 11.4 ± 0.4 years) children were recorded with 64 channels during a phonological lexical decision task (Kronbichler, in press). Words (W), pseudowords (PW), pseudohomophones (PH) and false fonts (FF) were visually presented and the participants had to decide whether an item sounded like a word (Taksi-Taxi) or not (Tatti, FF-items).

Topographic group differences (TANOVA: $P < 0.01$) were determined for each condition and for the contrasts PH-W, PW-W, PW-PH, FF-W in the interval 0–700 ms.

Extended periods with different topographies were found for W, starting at around 500 ms and 100–150 ms later for PH. The contrast PW-W revealed a negativity over the centro-parietal scalp (~480–510 ms) which was more pronounced in normal reading children and resembled the N400 incongruency effect found in sentence reading tasks. A similar, but less pronounced group difference was found for the PW-PH contrast ($P < 0.05$). In conclusion, the diminished N400 in dyslexics may reflect a different processing strategy and/or less automated lexical access.

Number of neurons, not number of action potentials are reflected in the VEP amplitude

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The components of the visual evoked potential represent different processing stages in the visual system. Their amplitude depends on the number of neurons processing the stimulus. The 'two component' theory proposed by Victor and Zemon (1985) divides visual processing into a luminance and a contrast mechanism, with the former preceding the latter. The activity of the first process is linked to the mean stimulus luminance. We investigated whether the activity of the luminance process depended on the mean stimulus luminance or the number of cells affected by the contrast reversal. The area affected by the contrast reversal was 50%, 37.5%, 25% and 12.5% of the total stimulus area. The mean stimulus luminance was varied by presenting the dartboards against a black or a white background. Root-mean-squared versions of the dartboard images were also presented. These were also set against a black or white background. The EEG activity of 23 healthy, adult volunteers to four series of dartboard stimuli was assessed. The amplitude of the early VEP components varied with the total

stimulus area affected by the contrast reversal and not with the mean stimulus luminance. We concluded that the VEP signal generated by luminance mechanism reflects neuronal recruitment not neuronal activity.

A neurophysiological measure of speech processing in kindergarten improves prediction of reading fluency in 2nd and 5th grade

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Dyslexia is a disorder of learning to read, marked by phonological deficits and familial risk. While dyslexia can only be diagnosed after reading instruction in school, phonological tests in preschool may allow early detection and intervention. We investigated whether neurophysiological measures in kindergarten could improve behavioral prediction of reading ability in school. Using Mismatch Negativity (MMN) paradigms we obtained neurophysiological measures of automatic tone and phoneme discrimination from kindergarten children with and without familial risk. We correlated MMN and behavioral (phonological ability, letter knowledge, IQ) measures in kindergarten with reading fluency in 2nd and 5th grade. In multiple regression analyses the lateralization of the late phoneme MMN together with behavioral measures explained 26% of the variance in reading fluency in 2nd grade across all children, and 41% in those at risk. For reading fluency in 5th grade the phoneme MMN was the only remaining predictor. The results suggest that a neurophysiological measure of speech processing in kindergarten adds to behavioral prediction of reading fluency in 2nd grade, and is more robust for predicting reading fluency in 5th grade. Neurophysiology thus can help dyslexic children receive timely intervention, especially if they have a familial risk.

Effects of chromatic ganzfeld stimulation on the brain's electrical activity II

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The reported study explored effects of homogeneous chromatic fields (ganzfeld) on the brain's electrical activity, as compared to brightness-equalised white ganzfeld. Three primary colours, red (R: $x = .655$; $y = .337$), green (G: $x = .285$; $y = .657$), blue (B: $x = .149$; $y = .054$) were used, and white light (W: $x = .309$; $y = .328$) as a baseline. Twelve subjects participated in the study, each in one session comprising three blocks (colour-W or W-colour, 10 min per condition), presented in permuted order. Before the session, the chromatic stimuli were individually adjusted to subjectively equal brightness with the achromatic stimulus W. EEG was recorded from 19 scalp electrodes. Fourier spectra were calculated from artifact-free two-seconds EEG epochs, averaged within conditions and subjects, and intra-individual normalised power differences were evaluated for the colour conditions (R, G, B) versus the respective achromatic stimulus (W). Red ganzfeld caused an increase of alpha2 power (10–12 Hz); blue and green ganzfeld caused a decrease of alpha2 and an increase of alpha1 power (8–10 Hz). The effects were observed mainly over the parieto-occipital region.

Nogo-N2 and Nogo-P3 in patients with borderline personality disorder

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Borderline personality disorder (BPD) is characterized by a variety of symptoms like emotional instability and impulsiveness. A diminished serotonergic turnover and/or dopaminergic dysfunction as well as reduced volumes of the hippocampus, amygdala, orbitofrontal cortex, and anterior cingulate cortex are discussed as underlying neurobiological mechanisms of BPD.

In the present study we examined 17 patients with BPD and seventeen age-, sex-, and education matched healthy controls using event-related potentials (ERPs). Participants performed a hybrid flanker-Go/Nogo task while multichannel EEG was recorded. We focused on two ERP components: the Nogo-N2 and the Nogo-P3, which have been discussed controversially in the context of response inhibition and response conflict.

Artifact-free EEG-segments were used to compute ERPs on correct Go trials (button press) and correct Nogo trials (no button press), separately. Patients with BPD showed smaller (less positive) Nogo-P3 amplitudes whereas groups did not differ with regard to the Nogo-N2.

Further studies are needed to exactly determine the underlying neuropsychological and neurobiological mechanisms resulting in altered Nogo-P3 amplitudes in BPD patients.

Nogo-N2 and Nogo-P3 in patients with obsessive-compulsive disorder

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Obsessive-compulsive disorder (OCD) has been related to a hyperactive cortico-striatal-pallidal-thalamic circuitry resulting clinically in an impaired inhibition of repetitive thoughts and behaviors.

We studied 13 patients with OCD and thirteen age-, sex-, and education matched healthy controls using event-related potentials (ERPs). Participants performed a hybrid flanker-Go/Nogo task while multichannel EEG was recorded. We focused on two ERP components: the Nogo-N2 and the Nogo-P3, which have been discussed controversially in the context of response inhibition and response conflict.

Artifact-free EEG-segments were used to compute ERPs on correct Go trials (button press) and correct Nogo trials (no button press), separately. Patients with OCD showed enhanced (more negative) Nogo-N2 amplitudes whereas groups did not differ with regard to the Nogo-P3. The present study replicates and extends previous findings of altered executive control processes in OCD patients.

Nogo-N2 and Nogo-P3 in patients with major depressive disorder

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Anterior cingulate cortex (ACC) and prefrontal cortex (PFC) are of main interest in neurobiological approaches to major depressive disorder (MDD). Several PET and fMRI studies have shown a hypoactivity in the dorsal subdivision of the ACC, the dorsolateral PFC, and the dorsomedial PFC in patients with MDD.

We studied 21 patients with MDD and 21 age-, sex-, and education matched healthy controls using event-related potentials (ERPs). Participants performed a hybrid flanker-Go/Nogo task while multichannel EEG was recorded. We focused on two ERP components: the Nogo-N2 and the Nogo-P3, which have been discussed in the context of response inhibition and response conflict.

Artifact-free EEG-segments were used to compute ERPs on correct Go trials (button press) and correct Nogo trials (no button press), separately. Patients with MDD showed smaller (less positive) Nogo-P3 amplitudes whereas groups did not differ with regard to the Nogo-N2.

To clarify how these group differences correlate with neuropsychological and psychopathological measures of depressed patients seems a reasonable target for further ERP studies.

Nogo-N2 and Nogo-P3 in more and less impulsive control subjects

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Electrophysiological correlates of impulsiveness were investigated in 26 healthy subjects using event-related potentials (ERP). Impulsiveness was determined by calculating individual reaction times (as function of general response speed) in order to split the entire group into two subgroups with a more controlled (low impulsiveness: LI; $n = 13$) and less controlled (high impulsiveness: HI; $n = 13$) response style.

Participants performed a hybrid flanker-Go/Nogo task while multichannel EEG was recorded. We focused on two ERP components: the Nogo-N2 and the Nogo-P3, which have been discussed in the context of response inhibition and response conflict.

Artifact-free EEG-segments were used to compute ERPs on correct Go trials (button press) and correct Nogo trials (no button press), separately. LI subjects showed enhanced (more positive) Nogo-P3 amplitudes than HI subjects. With regard to the Nogo-N2 groups did not differ.

Possibly, the Nogo-P3 mirrors impulsiveness in non-clinical samples. Alternative explanations due to intervening personality traits have to be ruled out by further studies.

Mapping familial aspects of brain functions in children and adults with and without ADHD

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Attention Deficit-Hyperactivity disorder (ADHD) is characterized by deficits in attention, inhibition and time processing, and is highly heritable.

We examined children suffering from ADHD (n = 31), their nonaffected siblings (n = 17), plus healthy control children (n = 23), as well as parents of the ADHD children with (n = 17) and without (n = 33) ADHD and control parents (n = 18) using event-related EEG mapping. Markers of inhibition (Nogo-P300) and preparation/time-processing (CNV) were examined for ADHD-effects, and for impairments present also in the nonaffected siblings/parents. We hypothesized that for some markers, the non-ADHD groups would resemble the ADHD-group rather than the healthy control children and parents. Such markers might represent vulnerability-factors or endophenotypes, rather than the phenotype defined by the ADHD-status.

Regarding inhibition, children and adults with ADHD had smaller Nogo-P300 than the nonaffected sibs and parents, respectively. Control children and control parents showed the highest Nogo-P300-amplitudes. Children showed a right posterior and adults a frontocentral Nogo-P300, reflecting typical generation effects.

Regarding time-processing, the CNV had a stable topography across generations. ADHD-children showed significantly weaker posterior-central negativity than control children. The nonaffected siblings were intermediate but closer to the control children. Parents (regardless of their ADHD-status) of children with ADHD showed a weaker (less negative) CNV than control parents.

These results suggest that the Nogo-P300 but not the CNV represents a potential endophenotype.

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Neurophysiology of hypnosis and meditation: common or distinct brain mechanisms?

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This study is the first to compare within the same subject changes in brain activity during two altered states of consciousness: hypnosis as compared to meditation.

The subject (male, 43 years old) is an advanced practitioner of Tibetan Buddhist meditation (Nyingma and Kagyu tradition) who has been practicing meditation for more than 18 years on a daily level.

He was assessed with a modified German version of the Harvard Scale of Hypnotic Susceptibility and was classified as highly-hypnotizable.

32-channel EEG was recorded at standard positions of the extended international 10–20 system.

Evaluations were Fast-Fourier spectral analyses during the following conditions: waking-rest in eyes-open and eyes-closed condition; early and late (deep) phases of hypnotic induction and meditation.

For each experimental condition, spectral power values were analyzed within the following frequency bands: theta 1 (3.71–5.57 Hz), theta 2 (5.57–7.42 Hz), alpha 1 (7.42–9.28 Hz), alpha 2 (9.28–11.13 Hz), beta (13–30 Hz) and gamma (30–49 Hz). The frequency windows of alpha and theta were adjusted by using individual alpha peak frequency as an anchor point. In both experimental conditions (meditation and hypnosis) the subject displayed significant higher amplitudes in alpha 1 frequency band as compared to the baseline condition. Findings were most pronounced at frontal, temporal and central positions. Interestingly, under deep hypnosis a highly significant global increase in theta 1 and theta 2 amplitudes was recorded. In contrast, no significant increases in theta power appeared under meditation. The neurophysiological approach revealed that meditation and hypnosis share common components, but there is also evidence for distinct neural correlates.

The findings advance our understanding of the neural mechanisms of different states of consciousness induced by psychological means.

Partially preserved spinothalamic tract conduction in spinal cord injury patients with neuropathic pain

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Neuropathic pain (NP) is a severe condition in spinal cord injury (SCI) and affects about 50% of all subjects. Although the reasons for NP are largely unknown, an involvement of spinothalamic tract (STT) dysfunction is highly probable. Here, functional STT integrity was assessed using contact heat evoked potentials (CHEP). Painful contact heat pulses which activate Aδ-fibres within the STT were applied on the skin. Cortical responses to these stimuli were recorded using electroencephalography. Measurements were executed both in

somatosensensory/motor complete and incomplete SCI. Three locations were investigated at different dermatomes on the back: one clearly above, one at and one three segments below the lesion. While CHEP were normal compared to controls above lesion level, damage to STT was shown in SCI subjects in the form of reduced/delayed or absent CHEP below the lesion. A preliminary comparison of CHEP in SCI subjects with and without NP tended towards discomplete STT lesions in NP, whereas NP-free patients either had totally absent or preserved CHEP below the lesion. This might support the theory that only partial STT lesions lead to NP.

Using sLORETA, cortical sources of the CHEP components will be compared between SCI patients and controls and patients with and without NP.

Clinical correlates with attention processing in obsessive-compulsive disorder as reflected by brain potentials

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But how a clinical severity impacts on attention processing in OCD is still unknown. To explore this question event-related brain potentials (ERPs) were recorded in a visual Go/Nogo experiment for attentional processes by ERP component P3b in OCD patients with either severe or moderate Y-BOCS scores (group S and group M, n = 7 each) and in normal healthy controls (n = 14). The OCD group S showed increased ERP amplitudes (N1 and P3b) compared to group M and controls. Statistically positive correlations were found between clinical symtomatology (obsession subscores) and the mean N1 amplitudes. Source analysis showed significantly higher localized brain activations at the left posterior cingulate gyrus for the target P3b in the OCD group S compared to the controls. The severely ill OCD patients showed attentional abnormalities (increased N1 and P3b), but not moderately ill OCD patients, which suggested a hyperactivity of striato-thalamo-cortical networks in these patients correlating to clinical severity.

Match and Mismatch of Taste, Odor and Color is Reflected in Human Electrical Brain Activity

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Words describing taste, odor, or color match particular words for food differentely well. We aimed at elucidating the relationship between odor, taste, color and food stimuli where subjects were studied either with questionnaires or in electrophysiological experiments. The reaction to appropriate or not appropriate stimulus combinations was of central interest.

First, 175 word pairs were rated by 660 subjects. We determind whether the first stimulus (odor or taste word) matched the second one (color or food word). Clearly matching or non-matching word pairs were used in an electrophysiological experiment. EEG was recorded from 30 electrodes in 24 healthy adults while words were presented on a monitor. Evoked potentials were computed for different stimulus classes.

Six components were identified and compared between conditions. For most components field strength (GFP) was lower for non-matching than for matching word pairs. At 124 ms latency there was a significant influence of stimulus class: food words yielded nearly identical GFP for matching and non-matching pairs while with color words GFP was significantly larger with matching stimuli. Similar effects were observed as early as at 100 ms latency.

Our results confirm earlier findings on of fast semantic processing in the visual cortex.

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Neuronal correlates of brand binding using members of the Coca-Cola brand community as study population: an EEG study extracting P300

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Brand binding is vital to the success of any company. We therefore investigated the neuronal correlate of consumers' brand-binding by comparing the brain electrical activity in a Coca-Cola brand community (n = 21) to stimuli associated with *Coca-Cola* or *Pepsi-Cola*. The stimuli consisted either of the brand color, the brand name or a photograph of a brand can. The evoked potential to each stimulus was recorded using 32 electrodes placed according to the international 10–20 system. Each brand specific stimuli was presented as both Standard and Deviant in a counter balanced oddball paradigm. The event-related potential was calculated from electrodes Pz and Fz. The P300 at both electrodes exhibited only the 'oddball' effect. Electrode Fz yielded a prominent P2 component that exhibited significantly larger amplitude to the image of the Coca-Cola compare to the Pepsi can as tested using a

multifactorial ANOVA. Localising of the neuronal correlates using sLORETA indicated that the difference in activation was due to brain structures associated with memory and emotion. The time point occurred already 126 ms after the stimulus event. From these results we concluded that the emotional aspects of a brand stimulus contribute to the early stages of its cognitive processing.

Affective semantic meaning of words and evoked brain activity in children

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According to the 'Semantic Differential' the connotative meaning of words can be quantified in statistically defined dimensions where every word is uniquely located on the three dimensions Evaluation (E), Potency (P), and Activity (A).

We studied 249 children between 9 and 18 years of age with questionnaires, and 19 children participated in evoked potential recordings. Words that belonged to different semantic classes were presented at random on a monitor, and EEG was measured from 30 channels. Evoked potentials were computed offline for the different word classes.

Varimax rotated factor analysis yielded the classical EPA dimensions that were identical to those obtained in adults. In the EEG data we observed significant effects of word class on component latency, field strength and topography. Similar as with adult subjects such effects occurred at short latency of about 100 ms after word presentation. The language-evoked components in children were similar but not identical to those reported previously for various groups of adults.

Our data confirm that the EPA structure is independent of age. In addition, electrical brain activity reflects semantic meaning at very early processing stages also in children.

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