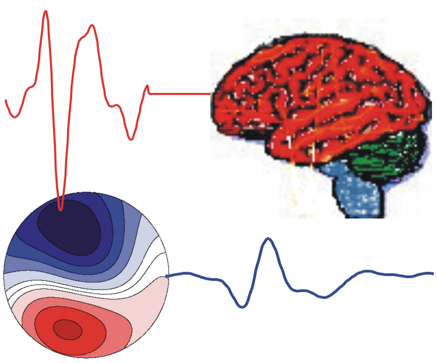
KOGNITIVE NEUROPHYSIOLOGIE DES MENSCHEN

HUMAN COGNITIVE NEUROPHYSIOLOGY



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Examples of reference format

Johnson, K., Hsiao, S., & Twombly, L. (1995). Neural mechanisms of tactile form recognition. In M. Gazzaniga (Ed.), *The Cognitive Neurosciences* (p. 253-267). Cambridge, Mass.: MIT Press.

Pascual-Marqui, R., Michel, C., & Lehmann, D. (1994). Low resolution electromagnetic tomography: a new method for localizing electrical activity in the brain. *International Journal of Psychophysiology*, *18*, 49-65.

Zani, A., & Proverbio, A. (Eds.). (2002). *The Cognitive Electrophysiology of Mind and Brain*. San Diego: Elsevier.

Editorial

This issue contains a long review paper by Pierre Etevenon on modified states of consciousness. Although this contribution is not a data paper, the reviewers felt that it is of general interest because of the subject areas – consciousness and meditation – that are controversially discussed in scientific publications, and because Dr. Etevenon has contributed to this discussion almost from its beginning.

I believe this summary is of interest to the readers. Of course such a personally flavored overview should be considered as a supplement to data papers published in the journal.

Wolfgang Skrandies

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Abstract

P. Etevenon (Hermanville sur Mer, France) — Meditation as a State of Consciousness: A Personal Account

Insofar as ”consciousness” is considered to be an axiom, different definitions of ”states of consciousness” can be envisaged. It was in Princeton and later in Paris in Pierre Deniker’s psychiatric clinic that the author first studied ”pathological states of consciousness” and ”natural states of consciousness”, together with quantitative EEG analyses of psychiatric and neurological conditions, as well as the effects of hallucinogenic and psychodysleptic drugs. In his opinion, ”states of meditation” and a wider category that he called in 1972 ”voluntary controlled states of consciousness” are distinct both from these ”altered pathological states” and from the ”natural states of consciousness” typical of wakefulness, sleep and dreams (particularly in paradoxical or REM sleep). In the Sainte-Anne hospital in Paris the first EEG recordings of the Zen master Taisen Deshimaru Roshi and his disciples were carried out and EEG spectral analyses computed. In two previous articles (1972 and 1973), the author validated by spectral analysis the high amplitude hypovariable alpha rhythm discovered earlier by Japanese scientists in their initial EEG explorations of zazen meditation. Throughout the past ten years, particularly in the United States, neuroscientists, continuing the work of Francisco Varela and Antoine Lutz, have made significant progress in studying states of meditation, mainly with respect to Buddhist practices. This review presents the author’s own point of view, and summarizes and discusses these recent findings from the perspective of his ongoing experience of thirty years of research, in which he argues that states of meditation are neither hallucinations nor sleep stages.

Keywords: Meditation, Consciousness, Electroencephalography, Brain mapping, Awareness, Wakefulness, Sleep stages, REM sleep, Dreams, Yoga, Buddhism, Zen

P. Etevenon — Meditation as a State of Consciousness: A Personal Account

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Introduction

Conscience, Consciousness and States of Consciousness

According to Coxeter (1974), ”the important principle [is] that any definition of a word must inevitably involve other words, which require further definitions. The only way to avoid a vicious circle (Synge, 1951) is to regard certain *primitive concepts* as being so simple and obvious that we agree to leave them undefined." If we want to avoid the kind of circular definitions that are to be found in dictionaries, we have to take into account those primitive statements called *axioms*. For "*The Man Who Saved Geometry"* (Roberts, 2006), the champion of n-dimensional geometry and builder of polytopes, a "point" was an axiom allowing further definitions of position, place, and extension as well as of line, plane, space, etc. In agreement with this great man, a materialist, I would, for my part, transpose his concept and argue that "*consciousness is an axiom*."

That basic primary concept enables us to define and construct different "*states of consciousness*." This point of view is not far removed from that of William James (1902), who, going beyond his empirical attitude, considered (in 1892) that consciousness is a constantly-changing flux: "When I say every 'state' or 'thought' is part of a personal consciousness, 'personal consciousness' is one of the terms in question. Its meaning we know so long as no one asks us to define it, but to give an accurate account of it is the most difficult of philosophic tasks." This again is because consciousness is an axiom, a basic primary concept from which different points of view emerge among visionaries, seekers of truth, philosophers and scientists, both in the past and in contemporary society.

Conscience and *consciousness* refer to two different concepts which were discussed by Roland Fischer in 1975: "As the Oxford English Dictionary points out, the English language adapted *conscience*, that is the 'privity of knowledge', from the Latin; so did the Romance languages. But the French, the Italian and the Spanish have but one word for both conscience and consciousness and only the context can assist in the differentiation of the meaning." Engelberg in 1972 considered that in German (as Hegel, Schopenhauer, Nietzsche, and Freud noted): "Conscience is *Gewissen* and consciousness is *Bewusstsein*". Roland Fischer recalled that around 1000 A.D. the monk of St. Gallen, Notker "teutonicus", used *gewissen* as a translation of the Latin *conscius* – "*so that Conscience originally also meant consciousness in the religious-moral sense*" – and went on to say that "the English and German languages, at least in common usage, sometimes behave as if they had forgotten the near identity of the two words which once in fact existed". Fischer points out that "in English 'conscious' as meaning 'inwardly sensible or aware' appears first in 1620, 'consciousness' in 1620 or 'the state of being conscious' in 1678, and 'self-consciousness' or 'consciousness of one's own thoughts' in 1690. It is also interesting that, according to Whyte (1959), 'conscious' whose Latin source had meant 'to know with' (to share knowledge with another) now came to mean 'to know in oneself, alone'."

In another article, Fischer (1972) analyzed the difference between what he called *objective 'I'-consciousness* and levels of *subjective 'Self'-awareness*: "We reserve the concept of 'consciousness' for a state of mind associated with the most intense objective (rational) *'I'-awareness 'out there.'* Each consecutive layer of self-awareness with diminishing objectivity 'out there' is accompanied by an increase in subjective *'Self' - Awareness*, experienced as *meaning 'in here'*."

For the French I.T. scientist Anceau (1999), the word *conscience* covers many notions and has two principal forms. In the first of these, it is a "state of arousal, of vigilance" which is manifested only during wakefulness and which disappears during sleep and in comas. The second form is the "epitome of superior psychic states", a characteristic peculiar to living creatures, and beyond that, to the whole universe – indeed, in some cases this form of conscience is placed in the same category as the divine. According to Anceau, although these two definitions may coexist, the second is spiritual; he then focuses on the first notion, which encompasses different forms of conscience implying or not reflection, memory, self-observation, thinking about thinking, feelings, etc. Anceau, who is an expert in parallel computing and the architecture of micro-processors, considers three main pathways that research into conscience can follow. The first is *dualist,* following Descartes (Eccles, 1989). The second, which is his own focus, is "*materialist, physicalist, methodological (and scientific)*" and is represented by Crick (1994), Edelman (1992), Dennett (1991), and in France by Changeux (1983), Dehaene et al. (2006) and Naccache (2006). (See also, more recently, *La conscience* 2008, and " *Consciences et Neuropsychologie 2010* "). The third current of opinion sees conscience as an extension of physics at the level of *quantum mechanics* (Penrose, 1994): behind the neuronal mechanisms lies a quantum hypercomputer made up of the neuronal cytoskeleton which is responsible for the process of conscience.

After this general introduction, let me now state my own point of view. To my mind, *conscience* is an axiom – more than that, indeed, for I would say that it is *primordial* in the meaning that Indian culture attaches to the word, without implying any spiritual or religious dimension (Etevenon, 1974; Etevenon & Santerre, 2006). I agree with Spinoza, who makes no separation between the body and the mind or spirit – my position is thus '*gnostic*' in John Scotus Erigena's sense; the latter's work has been looked at afresh by two mathematicians who were invited by Roland Fischer in 1967 for a meeting on "Interdisciplinary Perspectives of Time." There, Günther (1967) and von Foerster (Günther & von Foerster, 1967) described what they called "the logical structure of evolution and emanation" based on a new multivariate logic applied to the description and evolution of the universe. They argued that the universe can be looked upon as a sine wave oscillating around the median line of a quadrant in which the two orthogonal axes are (i) "*emanation*" (a word used by John Scotus Erigena, 810-877 A.D., who considered the universe to be a theophany, i.e. a revelation of God during the process of time) for the horizontal axis – a kind of supreme "determinism" – and (ii) "*evolution*" for the vertical axis – a "randomness" that makes for complete freedom in the genetic factory which is basically that described by Jacques Monod (1973). This is a "true monism" – a gnostic philosophical point of view that brings together both dualism and spiritualism with the materialist statements that are always mutually antagonistic. This is a major concept in Indian philosophy (Zimmer, 1953), which we find also in the writings of Sri Aurobindo (1949, 1970) and Jean Gebser (1949, 1985), who spoke of an "integral consciousness" and visited the Sri Aurobindo ashram in Pondicherry.

A History of States of Consciousness and Research on Meditation

The three main categories of states of consciousness

In 1965-1966, I was involved in post-doctoral research for NATO and thereafter worked as a research assistant. It was in Princeton that I first studied ” *pathological states of consciousness*” in animals and in human beings via the application of quantitative EEG analyses in researching, at the New Jersey Neuropsychiatric Institute (NJNPI), the effects of hallucinogenic and psychedelic drugs. The Institute was headed by Humphrey Osmond, the father of psychedelics, and I worked in the neuropharmacology department under the leadership of Leonide Goldstein, a pioneer and specialist in quantitative EEG. In Princeton, I studied the effects of intermittent light stimulation on the cortical visual area and subcortical visual thalamic nuclei of the rabbit. Specific lateralization of the electrophysiological responses and their variation after administration of LSD and amphetamine were studied. At doses producing hallucinations, these drugs induced hyperarousal and suppressed the previously observed ”cerebral dominance”. This LSD facilitation was antagonized by pentobarbital. (Etevenon, 1967; Etevenon & Boissier, 1972). I participated also (Etevenon, 1984) in experiments on the behavioral and EEG effects of psychedelic drugs on human beings. This was the period in which a great deal of research was being carried out on LSD and ”altered states of consciousness” (Tart, 1969). I shall not go into any more detail about this domain of research, which remains nonetheless a major theme of contemporary studies in the neurosciences and in medicine generally.

From 1967 to 1977, in Paris, I was a neurobiological scientist with INSERM (*Institut National de la Santé et de la Recherche Médicale*, the French equivalent of NIH) in charge of the ”Experimental neuropharmacological laboratory” of Research Unit U-320 INSERM, under the direction of J. R. Boissier. We proposed (Etevenon & Boissier, 1974) a theoretical model of schizophrenia which was an anticipation of the later model (Mahowald & Schenck, 1992) of dissociated mixed states of wakefulness and sleep. At the same time and for a further period, I studied the effects of psychotropic compounds on psychiatric and neurological patients in Pierre Deniker’s psychiatric clinic in the *Centre Hospitalier Sainte-Anne*; there, from 1977 until 1986, I was in charge of the ”Quantitative EEG laboratory”, part of the ”Laboratoire d’E.E.G.” of the Sainte-Anne hospital directed by Georges Verdeaux.

During these years I specialized in the quantitative EEG (Etevenon, 1985) study of ”pathological states” in human beings and of ” *natural states of consciousness*”, i.e. the different states of wakefulness and arousal, together with sleep stages and paradoxical sleep (REM). I studied, for example, the effects of the active compound of hashish (Deniker et al., 1974; Etevenon, 1978.) We compared and by cluster multivariate analysis (Etevenon, Pidoux & Rioux, 1979) were able to discriminate between quantified EEG recordings of two groups of schizophrenic patients (two subgroups: hebephrenics and paranoid schizophrenics, Etevenon et al., 1979) and two samples of paired control subjects (two subgroups: high-alpha and low-alpha subjects). After initiating in France EEG mappings with multiple electrodes (Etevenon et al., 1985; Walter et al., 1984), this procedure was applied to the EEG mapping of states of wakefulness under visual (Etevenon et al., 1985) or mental calculation tasks (Etevenon, 1986) and stages of sleep (Etevenon & Guillou, 1986). This enabled us to classify stages of wakefulness and sleep by means of increased EEG averaged amplitudes (square roots of EEG power values over posterior occipital and parieto-occipital areas): the minimum EEG amplitude was the desynchronized and activated EEGs recorded in "*active wakefulness, eyes open*" under a diffuse vigilance state followed by "*quiet wakefulness, eyes closed*" with high alpha activity amplitude (defined as $\geq 40\mu$V 'root-mean-square' over parieto-occipital and/or occipital areas, characteristic of "high-alpha" subjects). Between these two phases of "*external wakefulness*" we observed the two stages of what we called "*internal wakefulness*": the mean EEG amplitudes of "*stage 1 of drowsiness*", often simultaneously present with subjective hypnagogic imagery, and the mean EEG amplitudes of "*paradoxical sleep (REM)*", frequently associated with dreaming. I went on to make the first dynamic film of these EEG mappings from wakefulness to sleep stages (Etevenon, 1986, 1989), illustrating the time flux of dynamic and rapid EEG changes in successive brain mappings. I discovered also that, during REM periods and after wakening the recorded subjects and inquiring about their dream contents, the EEG mappings and EEG tracings showed selective activated areas related to the subjective dream contents (Etevenon, 1989). For example, when an activated left-side area was seen on the recorded left rolandic EEG location, in the dream content reported after wakening the subject was indeed using his or her right hand. However, the observed previous EEG mappings were "REM mappings" and not subjective verbal reports, after wakening, of actual "dream mappings". This is so because, in their dream reports, subjects may be carrying luggage, making a phone call or writing using their "right" hand, but the corresponding EEG mappings display only the stimulated and activated right hand over the contralateral "left" sensory-motor cortical area. This EEG activation then produces rapid frequency activity with low amplitude desynchronization over the contralateral "left" sensory-motor cortical area corresponding to an "active internal wakefulness state" of specific REM activation.

As in the preceding category of pathological states of consciousness, many papers have been published on the neuropsychobiology of natural states of consciousness, wakefulness, arousal, attention, and mental tasks, as well as on stages of sleep. New articles, reviews and books are constantly appearing, with some quite remarkable reports of new findings and network models (Dang-Vu et al., 2008; Hobson, 2009) in hypnology and oneirology, following the studies carried out by Michel Jouvet and his collaborators in Lyon (Jouvet, 2009; Beaubernard, 2009). I shall not for the moment comment on these breakthroughs, which lie outside the scope of the present review, focusing principally as it does on meditation.

The EEG appears to be a "marker of states of vigilance". "External wakefulness experiences" are linked to environmental stimuli and behavioral responses in the recorded subject. The activated EEG tracings are desynchronized, with small amplitudes and rapid frequency waves. Pfurtscheller's method – ERD (Event Related Desynchronization) / ERS (Event Related Synchronization) – is well suited to the study of successive periods of 125 ms accompanied by triggered external stimuli which may be sensorimotor, auditory (Lebrun et al., 1998, 2001), visual, or even emotional and/or cognitive complex tasks followed by recognition and/or choice responses (Pfurtscheller & Aranibar, 1977; Pfurtscheller & Lopes da Silva, 1999). On the other hand, synchronization and relaxation of visual areas induce high alpha activity similar to scanning alpha waves (Walter, 1953) during ”internal wakefulness experiences” in the course of attentional tasks performed by the recorded subject (Ray & Cole, 1985). These internal experiences resemble quiet meditative states (enstatic) that Roland Fischer called ”trophotropic” (Fischer, 1971, 1975, 1976), as opposed to ”ergotropic” meditative states (ecstatic). Consequently, it is extremely important that groups of normal control subjects be very well-paired: same age range, right-handed, same sex ratio, balanced high alpha/low alpha or chosen high alpha for greater EEG dynamics, same socio-cultural level, etc. Moreover, it is necessary to habituate them to the EEG laboratory settings, or, depending on the experimental protocol, to the MEG, MRI or fMRI settings. According to Leonide Goldstein (Goldstein, 1979, 1983; Etevenon, 1986) and to Francisco Varela (Varela, 1995; Varela et al., 2001), it is very important to interview the subject before, during and after an experiment with EEG recordings or other brain imagery technique, in order to gain access to his or her ”inner subjective state of consciousness” in a neurophenomenological approach combined with a more objective research protocol (Lutz, 2002).

Since 1963, Indian tradition and culture have been of considerable interest to me, especially as regards the different methods and practices of *yoga* and states of meditation, as well as the practice of *zazen* in Japan. This interest prompted me to record with Henrotte (1969, 2001) and with Verdeaux in 1972, the EEGs of a Zen master (Deshimaru, 1981; Deshimaru & Chauchard, 1976) and his disciples and those of a Indianist scholar (Lilian Silburn) from the CNRS (cf. the chapter on Lilian Silburn in Descamps, 2006) trained in the *Shivaism of Kashmir* (Silburn, 1970, 1981-1985); this is a very intense form of meditation that reaches high ”peaks of consciousness” (Maslow, 1970) and gives rise to unusual states of consciousness such as ecstasy or enstasy (Eliade, 1958, 1967). As a consequence of this preliminary pioneering research, I considered ”*states of meditation*” to be part of a larger category of states of consciousness which at that time (1972) I called ”*voluntary controlled states of consciousness*”; these are different both from ”altered pathological states” and from ”natural states of consciousness” of wakefulness, sleep and dreams (mainly in paradoxical sleep / REM). As a result of several trips to India and Japan, beginning in 1970, my interest in the inner life and inner experiences (Masui, 1952) was also progressively manifested over time by the publication of several articles (Etevenon, 1974, 1994, 1999, 2007) and of four books (Etevenon, 1984, 1987, 1990; Etevenon & Santerre, 2006) containing essays on psychotropic drug effects, dreams, yoga, the physiology of wakefulness and sleep, and states of consciousness.

The fourth period of my research career, which began in organic chemistry in 1961 (my PhD dates from 1963) but soon drew me towards neuropharmacology and quantitative EEG (D.Sc. thesis: Etevenon, 1977) in psychiatry and neurology, took place in Caen (Normandy) from 1986 to 1999. There I set up the ”Laboratoire de cartographie EEG” (EEG mapping laboratory) in the ”Centre Esquirol” (the psychiatric center headed by the late Edouard Zarifian) and later in the INSERM Research Unit-320 headed by J.C. Baron (who is now in Cambridge). There I learned about and applied new protocols and EEG techniques in neuropsychology (Etevenon, 1992, 1993; Etevenon et al., 1999), working with normal volunteers, young subjects who were required to carry out complex attentional mental tasks or those requiring auditory selective attention. These protocols were pre-PET scan studies because the INSERM unit U-320 was centered on a PET scan camera.

The ”*modified states of consciousness*” (M.S.C.) described in France by by Georges Lapassade (1987) and later Juan Gonzalez include what Tart (1969) calls ”altered states of consciousness”, such as hypnotic states and trances, meditation, biofeedback training, etc. The ”*voluntary controlled states of consciousness*” that I described in 1972 can also be looked upon as a subset of these ”*modified states of consciousness*”; in it are to be found not only ”*states of meditation*” but also rare states of consciousness such as the ”s*hamanic trance*” practiced for many centuries in Mongolia and Siberia. This has very recently been studied in EEG mapping with source localization by Pierre Flor-Henry (2007) in Canada (as yet unpublished).
With this description as a backcloth, I can now set out a short history of research into meditation between 1970 and 2009.

Research into Meditation

Four main bibliographies have been published of studies on meditation and consciousness. The first (Timmons & Kamiya, 1970; Timmons & Kanellakos, 1974) was drawn up by neuroscientists at the Langley Porter Psychiatric Institute in San Francisco headed by Enoch Callaway. Joe Kamiya was a pioneer of alpha-wave biofeedback who, together with Elmer and Alyce Green (1970) at the Menninger Foundation in Topeka, Kansas, initiated studies and recordings of yogis. By 1970, more than 400 references had already been reported, beginning mainly in 1957 with the journal *Electroencephalography and Clinical Neurophysiology.* That review published some seminal papers – by Bagchi and Wenger (1957), who conducted their research on yoga exercises in India; by Kasamatsu, Okuma and Takenaka (1957) describing ”The EEG of ‘Zen’ and ‘Yoga’ Practitioners”; and by Das and Gastaut (1957) on ”Variations of the electrical activity of the brain, heart, and skeletal muscles during yogic meditation and trance.” However, some years later, in 1973, Gastaut stated that the conclusions of his 1957 paper written in collaboration with Das were erroneous because of an earlier misinterpretation based on unrecognized artifacts. At that time, I published two articles on spectral analysis of EEGs in the course of zazen posture and yogic meditation (Henrotte, Etevenon & Verdeaux, 1972; Etevenon, Henrotte & Verdeaux, 1973); in 1973, Banquet published his first article on transcendental meditation practitioners, which pre-dated that of Hebert and Lehmann (1977).

In the 1970s, three theoretical articles came to similar conclusions in presenting two categories of internal states of meditation. This is well summarized by Michael Murphy in the first chapter of *Scientific Studies of Contemplative Experience: an Overview* in the second major bibliography that I have mentioned (Murphy & Donovan, 1983, first edition); it brings together 1253 entries dating from 1931 to 1983. In it, Murphy writes: "Roland Fischer, Julian Davidson, and other researchers have proposed some ways in which internal states might be correlated with different physiological profiles (Fischer, 1971; Davidson, 1976)"; he goes on to say that "Julian Davidson, Roland Fischer, and others have distinguished between *two classes of meditation*, *those that relax and those that excite*, associating their effects with the *trophotropic and ergotropic* conditions of the central nervous system modeled by Gellhorn and Kiely (Davidson, 1976; Fischer, 1971, 1976; Gellhorn and Kiely, 1972)". That idea remains valid to this day, and echoes what I will later in this paper describe as "*meditation with objects"* and *"meditation without objects*."

A revised and completed edition of the "Murphy and Donovan bibliography" (1999-2009) has since been drawn up by the "Institute of Noetic Sciences" in California; this is freely available on the Internet (*IONS Bibliography on Meditation*). In their current database, the authors have recorded 4206 items, covering 1937 to 2009. This would appear to be the most extensive bibliography on the subject of meditation. Others have been published, such as that by Thomas Metzinger, with its 140 pages of references of books and articles on "Consciousness - Selected Bibliography 1970-2004" in philosophy, cognitive science, and neuroscience over the last 34 years; essentially, this is an attempt to classify the various debates that have taken place in English and in German (Metzinger, 1995). This too is freely available on the Internet.

Research in consciousness and into meditation began in 1960 (Anand, Chhina & Singh, 1961; Wenger & Bagchi, 1961) and developed mainly in the 1970s (Naranjo & Ornstein, 1971; Ornstein, 1972) after Maharishi Mahesh Yogi became, in 1967, a leader among "New Age" flower-people and an anti-drug advocate; his early followers were the Beatles, Mia Farrow, and Shirley MacLaine, soon to be followed by Clint Eastwood, David Lynch and others. Two names in particular were associated with the increasing amount of EEG research studies of "*Transcendental Meditation (TM)*", a repeated mantra and inner auditory meditation introduced by the Maharishi. These first two associates were Wallace (1970; Wallace & Benson, 1972) and Herbert Benson (1975, 1987, 1997; Benson et al., 1982; Benson & Proctor, 1985, 2003; Hoffman, Benson et al., 1982; Lazar et al., 2000, 2007); the latter was a cardiologist in Harvard and the well-known author in 1975 of a best-seller, *The Relaxation Response*, which was followed by several other books. Their focus of study was the biological and physiological changes occurring during T.M. and the discovery that a "wakeful hypometabolic physiologic state" (Wallace, Benson & Wilson, 1971) was associated with "decreased blood lactate" (Wallace, Benson et al., 1971). Benson is the most quoted author in the IONS bibliography (97 references), followed by Orme-Johnson (45 references including Orme-Johnson & Haynes, 1981) and by Wallace (23 references). Other scientists have criticized these pre-1990 results. According to Fenwick et al. (1977), for example, "EEG results showed T.M. to be a method of holding the meditators' level of consciousness at stage 'onset' sleep". They found no evidence to suggest that TM produced a hypometabolic state beyond that produced by muscle relaxation, any support for the idea that TM is a fourth stage of consciousness (Murphy & Donovan, 1983). A whole series of books containing papers on TM practice, from its early beginnings up to the present day, have been published, mainly in English-speaking countries and elsewhere in Europe – for example, those by Banquet (1973) in France and by Hebert and Lehmann (1977) in Switzerland – as well as articles from many other countries throughout the world.

From 1970 onwards, research into meditation has been sponsored in the United States not only by academic and governmental research grants but also with the financial support of private foundations and institutions such as the various T.M. societies and a University dedicated to the teachings of Maharishi Mahesh Yogi. Thus it was that in 1967, after "the publication of *Your Maximum Mind*, Herbert Benson launched the 'Mind-Body Medical Institute', a for-profit research and training initiative in behavioral medicine, in conjunction with the Deaconess Hospital in Boston and the Harvard Medical School" (Murphy & Donovan, 1983).

The New Age movement, with personal development training, multiple successive conferences and publications, was given significant support by the Esalen Institute (http://www.esalen.org/) founded in Big Sur, California, by Michael Murphy and Dick Price. They were joined in 1962 by Alan Watts and Abraham Maslow, and later by Aldous Huxley, Fritz Perls and early leaders such as Arnold Toynbee, the theologian Paul Tillich, Linus Pauling (who was twice awarded the Nobel Prize), Carl Rogers, B. F. Skinner, Virginia Satir, Buckminster Fuller, Timothy Leary and J.B. Rhine. Since both its founders were students of Frederic Spiegelberg, professor of comparative religion and Indic studies in Stanford, Esalen soon became a nexus of the 1960s counter-culture movement and a center for humanistic alternative education with a particular focus on Indian and Asiatic cultures. As a young man of barely 19 years, Michael Murphy visited the Sri Aurobindo Ashram in Pondicherry and all his later work and research was inspired by the "integral purna yoga" of Sri Aurobindo (Murphy, 1992).

Similarly, the 14^{th} Dalaï-Lama founded the "Mind and Life Institute" in 1990, which, with the help of the neuroscientist Francisco Varela, developed research, still very much alive, into Buddhist meditation (Mind and Life, I to VIII, 1989, 1990, 1992, 1995, 2000). This research is at present being followed up in different neuroscience centers throughout the world by scientists such as Richard Davidson (Davidson & Davidson, 1980; Davidson & Harrington, 2002) and Antoine Lutz (Lutz et al., 2002, 2004, 2007, 2008) who is an associate scientist at the Waisman Laboratory for Brain Imaging & Behavior at the University of Wisconsin-Madison directed by Davidson.

The major themes of the 4206 items in the IONS bibliography have the following overall frequency, classified according to key-words:

Meditation 1696 items; Transcendental meditation 539 and ”t.m.” 383; Consciousness 192; Yoga 149; Zen 142; Brain Imagery : EEG 102, MEG 2, MRI 2 including 1 fMRI, TEP 9; Buddhist 82 and Buddhism 51; compassion 8 and empathy 17; vipassana 21; kundalini 9. This list represents 81% of all of the items in the IONS bibliography items, so that the key-words can in themselves be considered significant.

I will now focus my attention on the history and results of the earliest EEG studies of zazen posture meditation. These have given rise to some interesting findings which have been verified in subsequent studies. I shall then go on to summarize some recent studies of meditation in the neurosciences.

Early EEG studies of zazen meditation

Just as Wallace and Benson are renowned for their work and writings on transcendental meditation, two names are associated with studies of the practice of Zen meditation, and in particular on the ”zazen sitting posture of meditation” (Coupey, 2006) in which subjects sit cross-legged for 30 minutes without moving, in front of a blank wall, their eyes half-closed looking towards the tip of their nose. Akira Kazamatsu initiated these studies (Kasamatsu, Okuma & Takenaka, 1957; Kasamatsu et al., 1958) and was followed in 1960 by Tomio Hirai with his ”electroencephalographic study of Zen meditation”, a field of study which he continued to explore (Hirai, 1974). In their work together (Kasamatsu & Hirai, 1963), they went on to illustrate their″electroencephalographic study of Zen meditation” (Kasamatsu & Hirai, 1966) which proved to be of considerable interest. Both were physicians at the University of Tokyo, studying changes in EEG occurring during meditation in Zen masters and their disciples (48 in all from the Soto and Rinzai centers in Japan); these were divided into 3 groups, based on length of practice, and were compared with a control group of 18 subjects and 4 older subjects with no experience of meditation. Kasamatsu and Hirai made EEG recordings of 12 channels together with polygraph measurements (pulse rates, respiration, galvanic skin response), and tested responses to sensory stimuli during meditation. They found (Kasamatsu and Hirai, 1966) that there are *four successive phases in the time-course of zazen meditation*:

Stage 1: Characterized by the appearance of alpha waves (8-12 Hz) despite eyes being half-open.

Stage 2: Characterized by an increase in the amplitude of persistent alpha waves.

Stage 3: Characterized by a decrease in the frequency of alpha waves.

Stage 4: Characterized by the appearance of rhythmical theta trains (7 Hz) at the end of the 30 minutes of meditation.

In addition, a ”*modulation of the amplitude of alpha waves*” occurred together with the blocking of theta frequency trains when the meditators heard repeated clicks.

I have observed the same results when recording a Zen master in the Sainte-Anne hospital in Paris (Taisen Deshimaru Roshi) with his disciples (Etevenon, Henrotte & Verdeaux, 1973). Later, in his book on Zen and the brain (Deshimaru & Chauchard, 1976), Deshimaru proposed an interesting structural and functional-analysis diagram of zazen and brain neuronal centers. Paul Chauchard suggested that the ”*body image*” and the *”I” image* in the corresponding nuclei of brain networks betray relaxation during zazen meditation. By applying EEG spectral analysis (Etevenon, Henrotte & Verdeaux, 1973), I discovered that, in the course of zazen meditation, there is a highly hypovariable alpha peak corresponding to a sharp resonant alpha spectral peak together with alpha amplitude modulation; this can easily be seen by the EEG envelope. In a subsequent publication (Ribemont, Etevenon & Giannella, 1979), I put forward a method of ”zoom-FFT” for studying the alpha range and looking for hidden sharp frequency spectral EEG generators. This idea has recently been taken up by Tognoli (Tognoli et al., 2007) via a new application of complex EEG Time-Frequency Analysis (complex Morlet wavelet), although it has not yet been applied to the study of EEGs of zazen meditators. I went on to pioneer the application of a Hilbert transform to EEG instead of a Fourier transform for revealing the amplitude modulation of EEG (AM-EEG) (Etevenon, 1977); this new technique was subsequently adopted in neuropsychology protocols (Etevenon, et al. 1999), although not yet in studies of Zen meditation. These innovative methods of EEG analysis could now be applied to ongoing studies of meditation in the neurosciences.

Studies of Zen meditation have continued since then. James Austin (1999, 2006) published an essay on ”Zen and the Brain: Toward an Understanding of Meditation and Consciousness”, and this was followed in 2006 by an important paper on ”Zen-Brain reflections”, linking modern neuroscience research findings with Eastern philosophy from the perspective of the unique Zen experience. Subsequently, Kahana (2001, 2006) discussed the two rhythms that evidence particularly strong behavioral correlates: the 4–8 Hz theta rhythm and the 30–80 Hz gamma rhythm. It has been demonstrated that theta trains occurring during zazen meditation may be related to a working memory of maintaining a stable and steady zazen posture. Gamma rhythm is perhaps simply masked by the high alpha rhythm which can also be looked upon as an inhibition of visual areas. During zazen, when attention is mostly directed inwards in order to monitor body sensations and the flow of ongoing thoughts, alpha activity may also be enhanced, as Ray and Cole point out in the title of their paper (1985), because ”EEG alpha activity reflects attentional demands, and beta activity reflects emotional and cognitive processes”. Lehmann and his collaborators in Zürich (Lehmann et al, 2001; Tei et al., 2009) are also developing this line of research by means of new brain ”EEG source” imaging techniques (LORETA), comparing meditators with non-meditators, and also altered states of consciousness with the experience of the self.

We need more research on this topic, because meditation studies may well give rise to key indicators that will enable the neurosciences to act as a bridge between different fields of our current knowledge.

Recent studies of meditation in the neurosciences

Francisco Varela (Varela, 1979, 1995, 1999; Varela & Shear, 1999; Varela, Thomson & Rosch, 1991) was a Chilean biologist, philosopher and neuroscientist who, together with his mentor Humberto Maturana, brought the concept of *autopoiesis* into biology (Varela & Maturana, 1980). He became a Tibetan Buddhist in the 1970s. In 1986, he settled in France, where he first taught cognitive science and epistemology at the CREA in the *École Polytechnique*, and neuroscience at the University of Paris. From 1988 until his death in 2001 he led a research group at the LENA-CNRS with Jacques Martinerie *(Centre National de Recherche Scientifique*; Varela et al., 2001). The LENA had been founded and headed by Antoine Rémond at the Pitié-Salpêtrière hospital in Paris; Rémond pioneered studies in quantitative EEG of spatio-temporal EEG maps and evoked potentials (Remond, 1971-1978). In his 1995 keynote paper, Varela devised a new EEG method for analyzing brain waves involving ”*Resonant cell assemblies: A new approach to cognitive functions and neuronal synchrony*”. He brought together successive time-events of 500 ms duration, which Lehmann later considered to be like ”quanta of thoughts” of 100ms minimal epochs (Lehmann et al., 1998), brain electric microstates and momentary-conscious mind states. Varela associated these time-events with behavioral events, size of neuronal assemblies, EEG coherence measurement in the high frequency gamma band, and topography of synchrony between neuronal assemblies.

This EEG neural synchrony method was soon applied in Paris to complex psychophysiological tasks (Lutz, 2002; Lutz et al., 2002), together with a first-person approach to neurophenomenology. When Antoine Lutz went to the United States, he continued this approach through his studies of Buddhist meditators in Madison with Davidson (Brefczynski-Lewis, Lutz et al., 2007; Lutz et al., 2004, 2007). In his 2004 PNAS paper, Lutz et al. developed the idea that ”*long-term meditators self-induce high-amplitude gamma synchrony during mental practice*”. I have reviewed this article – which is highly technical – in the first part of ”States of consciousness” in my most recent work (Etevenon & Santerre, 2006), together with 17 other major new papers on meditation studies in the neurosciences, including that by Sara Lazar (Lazar et al., 2005). In her papers, Sara Lazar, working in Boston in collaboration with Herbert Benson’s group, noted (2000) that in applying functional magnetic resonance imaging (fMRI) ”the practice of meditation activates neural structures involved in attention and control of the nervous system”. Later, in 2005, by applying magnetic resonance imaging (MRI), they discovered that the ”meditation experience is associated with increased cortical thickness” when ”meditation insight” is being practiced; this implies that ”cortical plasticity is associated with meditation practice” (op. cit.).

Nowadays, as in the 1970s, meditation is again being studied in the neurosciences, especially in brain imagery laboratories. Recent findings open up new horizons either with respect to our fundamental understanding of what takes place or for practical purposes, such as alternative treatments in medicine and psychotherapy, including maintaining the well-being of mind and body during the aging process. New theses are being published along these lines, while the history of meditation research (Cahn, 2007) still considers meditation to be an ”altered state of consciousness”. I have already argued that meditation has more to do with ”voluntary controlled states of consciousness” (Henrotte, Etevenon & Verdeaux, 1972; Etevenon, Henrotte & Verdeaux, 1973; Etevenon & Santerre, 2006), which itself is part of a broader set of ”modified states of consciousness”. My principal argument is that meditators can enter into a meditative state, stay there if they like for some considerable time, and also leave it whenever they want to – whereas non-meditators will usually enter into the first stages of sleep after remaining quiet and sitting with their eyes closed for 12 minutes. Cahn and Polich (2006) have published a paper on ”Meditation States and Traits: EEG, ERP, and Neuroimaging Studies” and, more recently, one on the vipassana Buddhist type of meditation (Cahn & Polich, 2009, 2010; Cahn, Delorme & Polich, 2010), changing the P300 Event-Related Brain Potential. An additional paper on even more recent findings on meditation and the neurosciences – from basic research to clinical practice – is forthcoming (Braboszcz, Hahusseau & Delorme, 2010), and new articles and papers by Davidson and Lutz will constantly update the state of the art and our developing scientific knowledge of meditation. New material is regularly being published on this topic, such as that by Andrew Newberg (Newberg, d'Aquili & Rause, 2002; Newberg & Waldman, 2009) who coined the word ”neurotheology” after studying the effect of praying on the EEG. Newberg's research has been criticized from two main perspectives. Firstly, from a religious point of view, the study of practices such as meditation cannot be extrapolated as such to the broader area of religious and spiritual phenomena; secondly, from a non-religious perspective, Newberg has been criticized for not in the end reducing religion to brain functioning, a view held by some other neuroscientists. This debate has been going on since the 1970s, but the increasing amount of new findings concerning the specificity of meditative states is making it more and more difficult to consider meditation as simply a pathological hallucinatory and internal behavioral experience.

Conclusion and further perspectives

Results obtained over the previous ten years (Etevenon & Santerre, 2006) tend to indicate that *two categories of meditation* are henceforth to be taken into consideration.

Meditation ”with an object” involves several techniques: zazen, which begins with concentration on respiration and posture; respiratory yoga techniques, such as pranayama; repeated phrases like prayers or sanskrit mantras (T.M.), in which auditory stimulation is maintained thanks to sustained attention; visually-reinforced stimuli when focusing steadily on a point, the light from a candle, a religious picture or icon, a mandala, a yantra or a specific inner visualization; and other meditation techniques such as kundalini yoga (Silburn, 1983), yoga nidra, vipassana (Ricard, 2008; Ricard & Thuan, 2000), ”insight” meditation, etc.

This kind of ”meditation with an object” activates the brain areas and networks related to the focused ”object” and is represented by activated zones in 2D or 3D brain images by high resolution EEG with source localization (Brefczynski-Lewis, Lutz et al., 2007; Lutz et al., 2004), fMRI and MRI techniques (Lazar S. et al., 2000, 2005), or PET scan studies (references from the Institute of Noetic Sciences: *IONS Bibliography*). These activated areas can be both cortical and sub-cortical.

Meditation ”without an object” corresponds to techniques such as advanced zazen meditation – hishiryo, amala, satori, sunyata states of high consciousness as described by Deshimaru (Deshimaru and Chauchard, 1976); samadhi states and higher states of consciousness (Fischer, 1971, 1975, 1976; Gebser, 1949, 1985; Sri Aurobindo, 1970); Shiva consciousness in the Shivaïsm of Kashmir (Silburn, 1970, 1977, 1981-1985, 1983); universal compassion in Buddhism (Silburn, 1977; Ricard, 2008); and so forth.

As a counterpart to the preceding type, ”meditation without an object” relaxes and deactivates the brain areas and networks related to forgotten or unfocused objects such as the ‘I’, as well as brain areas linked to time and/or space percepts and concepts. This is represented by deactivated zones in 2D or 3D brain images together with increased synchrony between large assemblies and populations of neurons ((Brefczynski-Lewis, Lutz et al., 2007; Lutz et al., 2004). These deactivated areas can be both cortical and sub-cortical.

Further perspectives

A whole new philosophical vocabulary has come to the fore: neurophenomenology, neurophilosophy, neurotheology and, more recently, neuroeconomy, neurocybernetics, neuroethics, neuroesthetics, etc. Each of these terms argues in favor of a particular conception of states of consciousness, based upon and explained by specific relationships and connectivity in the neurodynamics of the brain and its networks.

Walter Freeman, who set up the Freeman Laboratory for Nonlinear Neurodynamics in Berkeley, is very much in the forefront of these theoretical ventures; he has written some highly important seminal books (Freeman, 1975, 1995, 2000), together with a significant number of research and teaching articles.

Matters of free will and determinism have been under discussion for some time now (Fischer, 1967, 1971, 1975, 1976). Lazar (Lazar et al., 2000, 2005) formulated one such question thus: is the individual brain predisposed to being particularly conducive to meditation or is it the practice of ”insight meditation” itself which increases the thickness of specific brain areas? That, of course, evokes the well-known question about which came first, the chicken or the egg; in 1965 at the MIT in Boston, I was told that this was the kind of question that only a bird could ask! Multiple causality is quite possible; in my D.Sc. thesis (1977), I applied the sophisticated but linear Gersch analysis (Gersch, 1972) of ”causality and driving in electrophysiological signal analysis” and went on to put forward some hypotheses on parallel versus serial functioning of large assemblies of neurons (Etevenon, 1992).

New protocols of research into meditative states may be developed and studied, bringing together data from the latest techniques of brain imagery in order to enhance our understanding of ”modified states of consciousness” (M.S.C.), including not only meditation but also shamanic trance (cf. Pierre Flor-Henry’s innovative recordings of Corine Sombrun in Edmonton [personal communication]), hypnosis (Rainville and Price, 2003; Grant & Rainville, 2005), N.D.E. experiences, neurofeedback studies, ”lucid dreaming” as a form of ”proto-consciousness” (Bouchet, 1994; LaBerge, 2000), REM states in sleep and dreaming (Hobson, 2009), etc.

In addition, philosophical works have been published by Sri Aurobindo (1949, 1970), by Jean Gebser (1949, 1985) and by those who initiated the present trend towards *integralist philosophy* (Combs, 2002; Feuerstein, 1987). In their reflections on the stages of evolution of human beings, they argue that after our present "mental structure (Jean Gebser) or plane (Sri Aurobindo) of consciousness" an *integral* structure or *supermind* plane of consciousness will gradually evolve. We may therefore look forward to further discoveries arising from prospective studies of meditative states by the neurosciences; these may well indicate a positive evolution of human beings and society, leading towards the development of integral or supermind consciousness. As François Rabelais put it, "science sans conscience n'est que ruine de l'âme" ("Knowledge without conscience is but the ruin of the soul").

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Abstract

K. Suzuki & H. Shinoda (Tokyo, Japan) — Error-related Components and Impulsivity Related to Speed and to Accuracy Trade-off

We examined the neurophysiological aspect of impulsivity as defined by performance. 71 participants were classified into 3 subgroups by determining response time (RT) and rate of incorrect responses on an arrow version of the flanker task: the impulsive group (+1SD above average or higher in incorrect response rate), the average group (values in the range of mean ±1SD of RT and incorrect response rate), and the remaining group. 7 participants from the impulsive (6 males and 1 females) and the average group (5 males and 2 females) were investigated using error-related components. Compared to the average group, a lower activity of error-related negativity (ERN/Ne) in the impulsive group was found as both the amplitude and topographical differences. However no difference in error positivity (Pe) was seen in ether group. These results suggest that an inability to adjust the behavior underlying impulsivity is associated with the ERN/Ne activity.

Keywords: Error-related negativity or error negativity (ERN/Ne); Error positivity (Pe); Behavioral adjustment; Impulsivity

K. Suzuki & H. Shinoda — Error-related Components and Impulsivity related to Speed and to Accuracy Trade-off

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Introduction

In response time (RT) tasks, participants search for an optimal RT band to achieve the appropriate balance between speed and accuracy Rabbitt and Vyas (1970). If they respond faster than the optimal RT band (i.e. risky response), accuracy is decreased, whereas if they respond more slowly (i.e. caution response), accuracy does not change. Individual differences in strategies between speed and accuracy exist, and some participants show a preference for risky response. Kagan (1965) defined the tendency to show a preference for a risky response as impulsivity. This definition of impulsivity was not associated with impulsivity measured by questionnaire (Block, Block, & Harrington, 1974;

Leshem & Glicksohn, 2007), but considered a separate dimension of impulsivity Dickman (1993); Leshem and Glicksohn (2007). Since self-monitoring their response is important for participants when searching for an optimal RT band, the neural system of monitoring behavior may operate differently in individuals with the impulsivity related by speed and accuracy trade-off. The process of behavior monitoring can be investigated using error-related negativity or error negativity (ERN/Ne) and error positivity (Pe) (Falkenstein, Hoormann, Christ, & Hohnsbein, 2000).

ERN/Ne is characterized by a negative deflection in response-locked event related brain potentials (ERPs) at the midline fronto-central area occurring during first 100ms following incorrect responses (Falkenstein et al., 2000; Gehring, Goss, Coles, Meyer, & Donchin, 1993). Several theories have attempted to explain the functional significance of ERN/Ne. Originally, ERN/Ne was thought to reflect the activity of an error-detection system comparing a correct response to an actual response (Bernstein, Scheffers, & Coles, 1995). More recently, researchers proposed a link between error detection and reinforcement learning in which ERN/Ne functions as a negative reinforcement learning signal conveyed to the anterior cingulate cortex (ACC) via the mesencephalic dopamine system (Holroyd & Coles, 2002). Another proposal posits ERN/Ne as part of a conflict monitoring system between correct and incorrect responses. According to this theory, ERN/Ne signals from the monitored conflict affect various control centers leading to top-down regulation for balancing responses, e.g., between speed and accuracy (Botvinick, Braver, Barch, Carter, & Cohen, 2001).

Following after the ERN/Ne, Pe is observed as a positive deflection over parieto-central areas (Falkenstein et al., 2000). Pe is associated with conscious error recognition and subsequent compensation (Nieuwenhuis, Ridderinkhof, Blom, Band, & Kok, 2001).

Although both ERN/Ne and Pe are involved in the behavior monitoring process, the effects on adjustment of behavior are different. In an anti-saccade task that requires a saccade to the opposite side of a peripheral abrupt onset cue, when participants make reflexive and unperceived errors which could not be corrected on the next trial, Pe was substantially reduced in amplitude while ERN/Ne was not (Nieuwenhuis et al., 2001). Moreover some studies reported that ERN/Ne was observed on correct trials (i.e., correct response negativity, CRN) but Pe was not (Bartholow et al., 2005; Vidal, Hasbroucq, Grapperon, & Bonnet, 2000). In contrast, the amplitude of ERN/Ne was larger for trials judged as certainly incorrect compared to trials judged as ambiguous (Scheffers & Coles, 2000). In terms of personality traits, obsessive-compulsive disorder (OCD) patients, who have negative emotions and engage in excessive self-monitoring, display larger ERN/Ne amplitudes than control participants (Gehring, Himle, & Nisenson, 2000). These findings suggest that Pe is specific to the error process and is directly associated with responses following incorrect trials, while ERN/Ne is not specific to the error process but is associated with the value and negative emotions of the participants.

In the present study, we examined the relationship between impulsivity as defined by performance and the error-related ERP components. Kagan (1965) measured impulsivity utilizing a speed and accuracy trade-off of performance on a task in which participants were asked to select the figure that exactly matches the standard from the alternatives. Alternately, a flanker task (Eriksen & Eriksen, 1979) has often been used to record error-related ERP components. Gehring et al. (1993) reported shortened RT and increased incorrect response rate in the flanker task with an increased demand for response speed. Hence we considered the individual differences of performance in the flanker task would reflect on the impulsivity.

Methods

Task

In an arrow version of the flanker task, participants were required to press a button with the thumb of their left or right hand as quickly and correctly as possible, corresponding to the direction of the central arrow flanked by four distracter arrows. Stimulus consisted of two compatible arrays, < < < < < and > > > > >. The probability of each these stimuli was .25. The stimulus was presented for 50 ms with stimuli onset asynchrony (SOA) of 2000 ms on PC monitor using STIM2 software (NeuroScan Inc.).

Participants and procedure

Participants were selected from a group of undergraduate and graduate students (42 males and 29 females, age = 23.0 $\pm$ 2.9 years old). After giving informed consent, they performed the flanker task before the main session. In the recruiting session, compatible trials gave a correct RT of 367.07 $\pm$ 42.43 ms and an incorrect response rate of 0.53 $\pm$ 1.39%. Comparable figure for incompatible trials gave a correct RT of 424.41 $\pm$ 45.89 ms and an incorrect response rate of 4.77 $\pm$ 5.25%. Importantly, the individual difference was significantly larger for incompatible trials than compatible trials ($F(70) = 14.22$, $p <. 001$). Moreover we found a significant negative correlation between mean correct RT and incorrect response rate for the incompatible trials (r=-0.40, $p <.001$, Figure 1A). Thus we split participants into three subgroups based on +1SD of grand mean correct RT and incorrect response rate for incompatible trials (see Figure 1A): The impulsive group (+1SD above average or higher in incorrect response rate), the average group (values in the range of mean $\pm$1SD of RT and incorrect response rate), and the remaining group. Agreeing to participate in the main session after the recruiting session were seven participants in the impulsive group (six males and one female, age = 22.3 $\pm$ 0.7 years old) and seven age-matched participants in the average groups (five males and two females, age = 22.5 $\pm$ 1.2 years old). Two participants in the impulsive group described themselves as being left-handed. The recruiting session consisted of 3 blocks of 48 trials after a practice (48 trials) and the main session consisted of 16 blocks.

EEG recordings

The electroencephalograms (EEGs) were recorded in 15 channels simultaneously from an array of electrodes located at F3, Fz, F4, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1 and O2. Vertical and horizontal

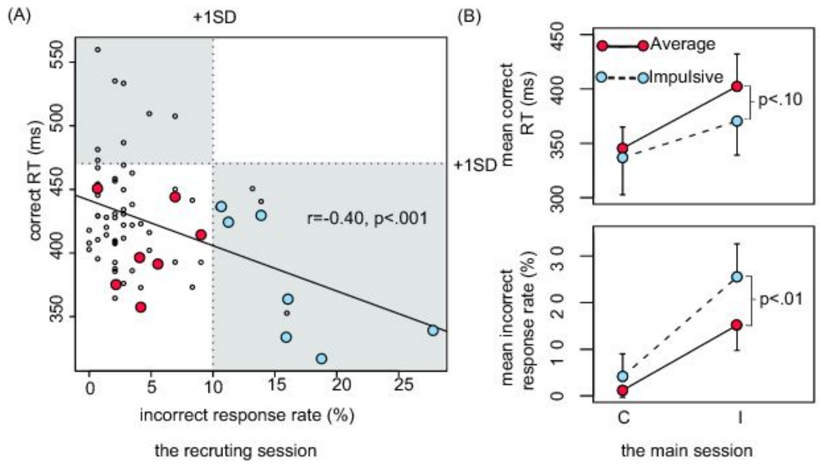

Figure 1: *Performance data. (A) Scatter plot of mean correct RT and incorrect response rate on incompatible trials in the recruiting session. The dotted lines represent the mean +1SD of grand mean correct RT and incorrect response rate. Filled red circles represent participants recruited in main session in the average group and filled blue circles represent those in the impulsive group. (B) The means (± SD) of correct RT and incorrect response rate between both groups for the compatible (C) and the incompatible (I) stimulus in the main session.*

electro-oculograms (EOGs) were recorded by electrodes placed above and below the left eye and the outer canthi of both eyes. Linked mastoids served as a recording reference. EEG and EOG were band-pass filtered between 1 and 50 Hz, and digitized at a rate of 500 Hz with NUAMPS (NeuroScan Inc.). Impedance was kept below 5 kΩ.

Data analysis

In order to evaluate behavioral adjustment following an error, we calculated post-error slowing and assessed double errors. Post-error slowing is calculated as the difference between mean RT following incorrect and correct responses. Since participants typically increase RT on the following trial after making an error (Rabbitt, 1966), post-error slowing reflects executing adjustment of behavior. Furthermore, double-error rate is calculated as the incorrect response rate following incorrect responses. Hajcak and Simons (2008) suggested that double-error indicated the failure to appropriately implement post-error adjustment.

EEG and EOG were segmented into epochs of 900 ms starting 600 ms (i.e. pre-stimulus) before response (button press) (Pailing, Segalowitz, Dywan, & Davies, 2002). Visual inspection was used to reject epochs which included artifacts such as eye blink and movement, and epochs were always rejected if EOG activity exceeded a range of 70 μV. The remaining epochs were baseline corrected pre-response and averaged for incorrect response on each trial. Because average number on compatible trials was not enough, event-related potentials (ERPs) for compatible trial were excluded from analyses. In order to focus on the temporal dynamics of potential field strength and topographical distribution, we analyzed GFP and centroid locations (positive or negative locations in the anterior-posterior or in the left-right direction) at each time point using average reference (Lehmann & Skrandies, 1980; Skrandies, 1987). GFP was computed as the spatial SD of overall voltages in each map and its peaks represents times of maximum overall field strength corresponding to latencies of the major ERP components. To examine the spatial characteristics of the brain electric field, the centroid locations were computed as the scalp position of the centers of gravity in the positive and negative map area.

Results

Behavioral data

Figure 1B shows the mean (± SD) for correct RT and incorrect response rate. We observed that individuals in the impulsive group had shorter correct RT and higher incorrect response rate compared to individuals in the average group. The difference was remarkable for incompatible trials. To analyze correct RT and incorrect response rate, we submitted to separate repeated measures analyses of variance (ANOVAs) with 2 groups × 2 compatibility as factors. We found a significant compatibility effect ($F(1, 12) = 140.74$, $p <. 01$) and a significant interaction of groups by compatibility ($F(1, 12) = 9.45$, $p <. 01$). The method of Holm (Holm, 1979) was used to adjust the P values in multiple testing. Holm tests revealed that compatible trials were shorter than incompatible trials in both groups ($p <. 01$). In addition, individuals tended to have shorter correct RT in the impulsive than the average group for incompatible trials ($p <. 10$). However, a significant group effect was not found ($F(1, 12) = 1.79$, $p = .20$). In terms of incorrect response rate, we found a significant compatibility effect ($F(1, 12) = 114.10$, $p <. 01$), a significant group effect ($F(1, 12) = 9.16$, $p <. 05$), a significant interaction of groups by compatibility ($F(1, 12) = 5.00$, $p <. 05$). Holm tests revealed that individuals had higher incorrect response rate in the impulsive than the average group for incompatible trials ($p <. 01$) and compatible trials showed a lower incorrect response rate than incompatible trials in both groups ($p <. 01$).

As to indices of behavioral adjustment, two samples t-tests were performed, and showed following results. Double-error rate was higher in the impulsive than the average group ($t(12) = -3.25$, $p <. 01$; average group = 6.67 ± 5.27%, impulsive group = 16.53 ± 6.03%). However, both groups did not differ in post-error slowing ($t(12) = 1.25$, $p = .23$; average group = 8.85 ± 10.75 ms, impulsive group = 2.83 ± 13.76 ms).

Electrophysiological data

Response-locked ERPs and GFP peaks

Figure 2A shows the grand mean response-locked ERP waveforms and GFP peaks evoked by incorrect responses in incompatible trials. Clear GFP peaks can be seen at 24 ms for the first component and at 156 ms for the second component in the average group and at 22 ms for the first component and at 138 ms for the second component in

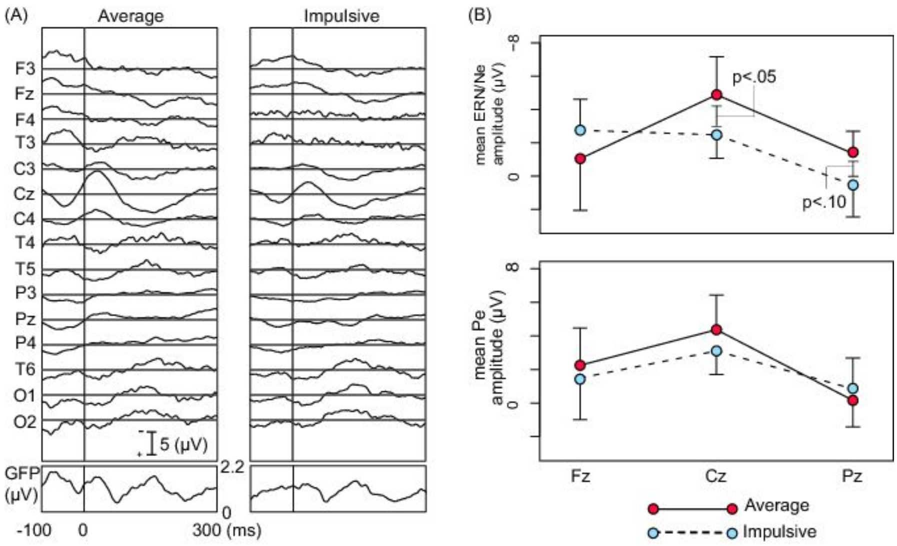

Figure 2: *Grand mean response-locked ERP waveforms on incorrect trials for the average and impulsive individuals. (A) ERP waveforms and GFP, (B) ERP waveforms at electrode site Cz, (C) Mean amplitudes of ERN/Ne and Pe at electrode site Cz between both groups.*

the impulsive group (Figure 2A, low). These components were identified as ERN/Ne and Pe. We compared difference of the mean GFP value and amplitude at Cz (Figure 2B) of ERN/Ne and Pe between both groups by two sample t-test and Welch's t-test. No significant difference was found between either group for the GFP value of ERN/Ne or Pe ($t(12) = 0.92$, $p = .38$; $t(7.6) = 0.76$, $p = .47$). For the amplitude of ERN/Ne and Pe (Figure 2B), ANOVAs with 2 groups $\times$ 3 electrodes (Fz, Cz, Pz) using Greenhouse-Geisser correction were performed. There was a significant interaction of groups by electrodes in the amplitude of ERN/Ne ($F(1,12) = 28.07$, $p <. 05$, $\varepsilon = 0.63$). Holms tests revealed that the difference of the amplitude of ERN/Ne at Cz ($p <. 05$) and a tendency level at Pz ($p = .05$). On the other hand, there were not a significant main effect of groups and a significant interaction of groups by electrodes in the amplitude of Pe ($F(1,12) = 0.46$, $p = .50$, $\varepsilon = 0.67$; $F(1,12) = 0.98$, $p = .36$, $\varepsilon = 0.67$).

Correlational findings

To investigate the relationship between ERP components and the number of errors, we performed correlational analyses between ERP components and incorrect response rate on incompatible trials. A tendency was found for the amplitude of ERN/Ne at Cz ($r = 0.48$, $p <. 08$), while there was not any significant correlation with the amplitude of Pe at Cz($r = -0.35$, $p = .22$). Furthermore, we analyzed the average and impulsive groups separately. For the impulsive group, we found a significant correlation with the amplitude of ERN/Ne at Cz ($r = 0.83$, $p <. 05$), whereas we could not find any significant correlation for the average group ($r = -0.35$, $p = .43$). Neither was there any significant correlation with the amplitude of Pe at Cz for the average group nor the impulsive group (r = -0.30, p = .49; r = -0.08, p = .85).

Topographical analysis

Figure 3A shows an ERP map series due to incorrect responses on incompatible trials. As can be seen, the change in ERP topography occurred between 0 and 40ms after the response. To investigate this difference (the occurrence of ERN/Ne) in detail, the centroid location was calculated. The trajectory of negative and positive centroids is illustrated in Figure 3B. Although the location of negative centroids in the average group moved from the anterior to the posterior, those of the impulsive group remained in the anterior area. The two samples t-test shows that the location of negative centroid in the Y direction (i.e. anterior from posterior) at ERN/Ne peak in the impulsive group distributed significantly more anterior than that in the average group (t(12) = 2.28, p <. 05).

Discussion

In the present study, participants who had a shorter mean correct RT tended to have a higher incorrect response rate while participants who had a longer mean correct RT tended to have a lower incorrect response rate in the flanker task. Based on this relationship between mean correct RT and incorrect response rate (i.e. speed and accuracy trade-off), we assessed impulsivity as the tendency to commit more errors and respond more quickly. In terms of behavioral adjustment, although post-error slowing did not significantly differ in both groups, these results suggest that individuals in the impulsive group needed to respond more slowly, as RT in the impulsive group tended to be faster than in the average group. Accordingly, the double-error rate was higher in the impulsive group when compared to the average group. A previous study reported that double-error indicated failure to appropriately implement post-error adjustment (Hajcak & Simons, 2008). Thus, individuals in the impulsive group may not adjust response adequately after incorrect responses.

More importantly, our findings indicated that this inability to adjust behavior in the impulsive group was associated with a decrease in the amplitude of the ERN/Ne component. Current computational accounts of the role of ERN/Ne in reinforcement learning theory (Holroyd & Coles, 2002) and conflict monitoring theory (Botvinick et al., 2001) predicted these results. These models suggest that an error or a conflict signal reflected by ERN/Ne leads to behavioral adjustment; empirical studies also show support for these results (Debener et al., 2005; Gehring et al., 1993). A study exploring single-trial ERN/Ne using independent component analysis reported that longer RT on subsequent trials were associated with higher amplitudes of ERN/Ne (Debener et al., 2005). Moreover, earlier studies showed that ERN/Ne amplitude covaried with perceived incorrect responses by participants (Scheffers & Coles, 2000). These findings suggest that individuals in the impulsive group are unsusceptible to the value of incorrect response.

In scalp field topography, we found that the negative centroids at ERN/Ne peak was central area in the average group while it was more anterior area in the impulsive group, although there was not a significant differ-

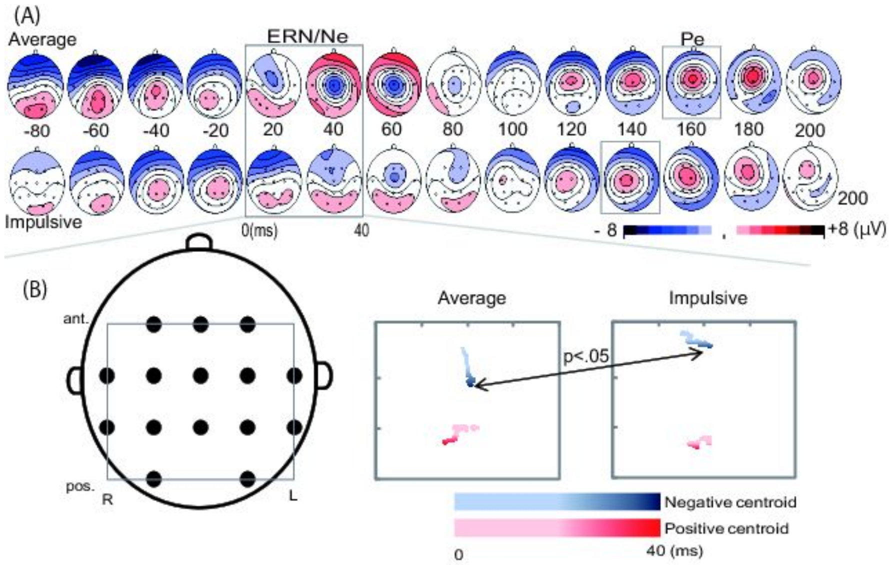

Figure 3: *ERP map series and the trajectory of the negative and positive centroids. (A) ERP map series from -80 to 200 ms (per 20 ms). Grey frames show maps including the occurrence of ERN/Ne and GFP peaks of Pe. (B) The trajectory of the negative and positive centroids from 0 to 40 ms.*

ence of the GFP value. In stimulus-locked ERP, P3 component was observed around the time of response onset, with anterior-negative/posterior-positive brain electric field (Volpe et al., 2007). It is possible that the effects of P3 component were larger in the impulsive group because ERN/Ne component was diminished, thus negative centroid at ERN/Ne peak in the impulsive group may have been located at more anterior area. Vocat, Pourtois, and Vuilleumier (2008) reported that the difference between ERN and CRN were not only found in the amplitude but also in scalp field topography. Therefore the difference of the location of negative centroids at ERN/Ne peak was reflected by distinctness of the value over central area (only at Cz).

Although several studies have shown that behavioral adjustment after an incorrect response is directly related to Pe rather than ERN/Ne (Nieuwenhuis et al., 2001), we did not observe significant reduced Pe in the impulsive group. In the present study, post-error slowing consistently showed no difference in both groups, while differences in the double-error rate were found. We considered that individuals in the impulsive group executed compensatory adjustment, as reflected by Pe, as well as individuals in the average group did, regardless of the effect on accuracy.

Impulsivity as presented in the present study is a subset of the broader dimensions described by this term. Some previous studies reported that impulsivity is related to ERN/Ne while others discount the relationship. Impulsivity, as assessed by response time differences between correct and incorrect trials, was correlated with reduced ERN/Ne amplitude (Pailing et al., 2002). Smaller ERN/Ne was also observed in individuals with high impulsivity related to performance of the stop signal task and personality traits (Stahl & Gibbons, 2007). However, the ranking of impulsiveness as one of the personality traits was not related to ERN/Ne (Santesso & Segalowitz, 2009). According to previous studies, at least, the impulsivity associated with task performance may be related to ERN/Ne.

The impulsive group had a higher incorrect response rate than the average group, so it is possible that the reduced ERN/Ne in the impulsive group reflects simple habituation. However, we believe that this likely is not the case for the following reason. If simple habituation affected ERN/Ne, there would be a positive correlation between ERN/Ne amplitude and incorrect response rate in both groups. Although a significant positive correlation was observed in the impulsive group, no significant correlation could be found in the average group (furthermore negative correlation was observed). We speculate that ERN/Ne was affected by response style rather than any habituation effect.

The present study had several limitations. First, the small sample size may be problematic. It suggests limited statistical power to detect statistical significance. Furthermore, the average and impulsive groups was not controlled for gender and handedness. Although the effects of gender and handedness might affect ERN/Ne components, we could not confirm them statistically because of the sample size. Future studies should use larger sample size in order to clarify these issues. Another limitation related to number of electrodes. In general, the amplitude of ERN/Ne was maximal at FCz and Pe was maximal at CPz (Falkenstein et al., 2000). However these channels were not recorded in the present study. Therefore, future studies should investigate GFP value and the locations of negative and positive centroids due to ERN/Ne and Pe using higher-density EEG recordings. Finally, although the impulsivity was defined with RT and incorrect response rate, we recruited participants in the impulsive group based on only incorrect response rate. Thus some of them had longer correct RT than some of participants in the average group. Moreover, the ability to engage in the flanker task is different in participants (e.g. the variety of incorrect response rate over participants who had same correct RT). These facts suggest the definition of impulsivity is ambiguous in the present study. However, in the view of speed and accuracy trade-off within a participant, a high incorrect response rate shows that response times were short for the participant (Rabbitt & Vyas, 1970). Thus, it might be appropriate to recruit the participants with incorrect response rate in the present study.

In summary, performance data (correct RT and double-error rate) indicates an inability by the impulsive group to adjust behavior. Differences in ERN/Ne activity in the impulsive group is seen in both lowered amplitude and topographical difference. These results suggest that the inability to adjust behavior in the impulsive group is related to relatively low values of ERN/Ne to incorrect responses.

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Altered prefrontal activation during decision-making in panic patients: impact of error feedback in previous trial.

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Previous research in decision-making could show that panic patients are more likely than healthy persons to change their behavioural strategy after the occurrence of an error. Such a pattern was interpreted as a permanent search for an optimal decision-making strategy in panic patients. The assumed anatomical basis of this process is a dysfunctional interaction between the anterior cingulate cortex (ACC) - as a monitoring system for errors - and the dorsolateral prefrontal cortex (dlPFC) - as the main regulation instance in decision-making. We investigated the role of the dlPFC during a simple decision-making task with a predefined error probability in a group of panic patients and healthy controls. Groups were compared in regard to strategy choices and brain activity during decision making for the two conditions 'error feedback in the previous trial' and 'positive feedback in the previous trial'. Brain activity was measured with near-infrared spectroscopy (NIRS) and electroencephalography (EEG); additionally, the skin conductance response (SCR) was recorded. Preliminary results suggest altered activation patterns in the dlPFC during decision-making in panic patients in comparison to healthy controls following an error feedback in the previous trial. Both spatial and temporal activation patterns show significant aberrances. Therefore, the assumption of dysfunctional dlPFC processes during decision-making in panic patients can be supported. Especially because of the altered temporal process, our result further underpins the notion of a modified influence of error-related information on subsequent decision making. Results are discussed regarding the role of altered error-processing in the maintenance of safety seeking behaviour and thereby of panic disorder.

Frontal midline theta reflecting working memory load: Influence of selected frequencies and of variability in behavioral effects.

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Frontal midline theta (4-8Hz) activity has been related to working memory (WM) processes, as it typically increases with WM load. The robustness of this effect, however, varies across studies and subjects, posing limits to its interpretation. We hypothesized that the frontal midline theta WM effect is not only topographically focal at anterior-frontal electrodes, but may also occur at a very narrow and individually variable frequency band. In addition, we hypothesized that individual variability in the behavioral WM effect may explain some variation in the frontal midline theta WM effect. We recorded a 63-channel EEG from healthy, young adults while they performed a visual WM task with unfamiliar symbols under low (2 items) and high (4 items) workload conditions. Preliminary results from the first 15 subjects show that higher workload led to less accurate and slower responses at the behavioral level (accuracy: 83.3 vs. 93.8%; reaction time: 1132 vs. 1000ms). While frontal midline theta increased with workload, this increase was only robust using individually determined theta peaks (AFz: 58.8%; t=4.09, p<0.01), but not for the mean theta band (4-8Hz; AFz: 10.6%; t=1.57, p=ns). In addition, the workload-dependent increase of theta activity was associated with a corresponding decrease in accuracy (individual peak: r=-0.52, p<0.05). This correlation also held, if only trials with correct responses were included in the EEG analysis, although only at trend level (r=-0.45, p<0.1). The results indicate that workload-related theta effects are not only topographically focused around frontal midline electrodes, but are also limited to narrow, individual theta frequency bands. The study also shows correlations between behavioral responses and changes in frontal midline theta, and thus strengthens the notion that frontal midline theta reflects active WM processes.

EEG parameter seen with successful golf putts.

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Continuous attention to a stimulus usually evokes a specific kind of cortical activity termed frontal midline theta (Fmθ). This Fmθ can be observed in the electroencephalogram (EEG) most pronounced at the frontal midline electrode location Fz and has been linked to several attention related processes, as action regulation, concentration, sustained and internalized attention. In general, it has been repeatedly shown that Fmθ is clearly linked to the amount of mental effort and attention. The fact that Fmθ is related to attentional processes led to the hypothesis, that these differences in the allocation of attention related resources, should be observable during the preparatory phase of a golf putt. 15 male participants with different experience in golf performed 100 putts (indoor) while multichannel EEG was recorded. For each putt the distance to the target position was assessed. According to the average performance the sample was split in a group of good and a group of bad golfer. The putts of each participant were divided successful and less successful trials. Fmθ activity was analyzed for four 500 ms time intervals (- 1500 to + 500) around the backswing of the putt. A three factorial ANOVA for TIME X PERFORMANCE X GROUP calculated for Fz, revealed significant results for TIME, PERFORMANCE, and TIME X GROUP. Fmθ power is most pronounced at about 1.5 sec before the swing of the putt and decreases towards the putt. Interestingly, this effect is significantly stronger for good golfers as compared to those with less experience. Finally more successful putts are preceded by a higher Fmθ power. Additional analyses indicated that these effects are reflected only at frontal electrode sites. Summarizing these results indicate that successful golf putts are preceded by higher Fmθ indicating more focused attention. These attentional processes are more pronounced in experienced golfers.

The functional meaning of human alpha oscillations for conscious perception.

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The amplitude increase of the human alpha rhythm in an experimental situation has for a long time been considered reflecting an idling process without any functional meaning. Recent studies show that not only the alpha decrease but also the alpha amplitude increase serve specific cognitive functioning, mainly the inhibition of task irrelevant brain areas or the inhibition of distracting information. In addition also the alpha phase seems to be important for the exact timing of neural activity to establish efficient perception performance. In one of our studies images were presented with different degradation levels and subjects were asked to indicate whether the presented image was a real or a nonsense object. The results show that within the time-window of object recognition alpha amplitude decreases stronger for real as compared to nonsense objects. Additionally, we found a stronger alpha network for real objects within this time window as derived from phase-locking analyses. We interpret this alpha-network as an important top-down mechanism that establishes the access to semantic long-term memory. A follow-up study was designed using video-sequences with the same task manipulation as in the first experiment. But, in this task, we did not have any ëventsänd, thus, can exclude any effects elicited by evoked activity. Preliminary data indicates that we can replicate the findings from the first study and we can extend the findings by showing that alpha is especially relevant for the processing of meaningful information when compared to simple processing of physical stimulus features. We conclude that the onset of alpha desynchronization reflects the time point of successful access to semantic long-term memory traces.

EEG LORETA lagged coherence during resting, attention to calculation and attention to breathing.

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Do different types of attention show related tendencies of intracerebral functional connectivity? 58-channel EEG of 25 healthy, meditation-naïve, right-handed, male students was recorded during three conditions of 5 minutes each with closed eyes in randomized order: (1) resting [3 runs], (2) mental arithmetic [2 runs], and (3) breath counting, a meditation initiation technique [2 runs]. Artifact]controlled EEG data were recomputed, for the 8 EEG frequency bands, into eLORETA intracerebral current densities. Interpretation of functional connectivity between brain areas when using head surface]recorded EEG suffers from (1) uncertainty about intracerebral source localization and (2) effects of volume conduction. Computing coherence via source modeling (e.g. LORETA) avoids problem (1), and excluding coherences with zero phase lag avoids problem (2). Accordingly, we computed ”lagged coherence” intracerebral connectivity between eLORETA current densities in 19 regions of interest. Averaged resting condition was compared to the breath counting and the arithmetic run of which participants post-hoc reported that their concentration during task performance was best. Paired t-tests between conditions yielded differences of coherence at $p<0.1$ (corrected for multiple testing) for 4 frequency bands (alpha1, beta2, beta3, gamma) [number of connections in brackets]: breath counting showed lower coherence than rest (all 4 bands [2,1,1,6]) and arithmetic (alpha1, beta2, gamma [1,2,2]); arithmetic showed higher coherence than rest (gamma [1]). In sum, of all three conditions, breath counting showed lowest demands on intracerebral functional connectivity. The results do not support generally increased coherence during attention. Instead, they suggest that breath counting and mental arithmetic induce mental states whose inter-area connectivity differs in several frequency bands. In the gamma frequency band, their inter-area connectivity differs in opposite directions from rest.

Special features of intraoperative monitoring during selective dorsal rhizotomy.

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In a selective dorsal rhizotomy (SDR), partial deafferentiation of specifically targeted sensory nerve roots is carried out through a minimal monosegmental inlet located above the conus medullaris. The decision as to which parts of the roots are to be transected is not left to chance, but is rather determined in the course of intraoperative neurophysiological monitoring (IONM). The following procedure is used for each side of the body, for every segmental level (L2 to S1), and for every rootlet: First the reflex threshold intensity is determined through repetitive single stimulation of the sensory nerve root, during which the response potential of the relevant muscle groups turns up on the electromyogram (EMG). A one-second 50Hz-train-stimulation is then administered in accordance with the determined intensity of reflex threshold. Subsequently the 50 Hz response is graded in keeping with precisely defined criteria ranging from 0 to 4. On the basis of this grading and the specific pattern involved, a partial section of 50 percent per nerve root is always performed. The stimulus responses in children with infantile cerebral palsy who suffer motor disturbances as a result of their disorder vary from case to case and often deviate from the physiological responses one would normally expect. The peculiarities which were at odds with basic rules of anatomy and physiology involve the following:

- spreading of segmental innervation into respective muscle groups
- intensity required in order to reach reflex threshold in dorsal nerve roots
- assumption that a right or left stimulation can result in reflex responses only in the relevant ipsilateral muscle groups.

In particular the special features of IONM will be elaborated upon. SDR is a microsurgical intervention. After more than 50 rhizotomies carried out at the Charité Hospital in the above-described manner, a striking reduction in spasticity was observed, along with substantial improvement in children's ability to walk.

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Evoked and induced event-related EEG oscillations in high-performing young and elderly individuals during a cognitive flexibility task.

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We conducted a study of normal brain aging that was based upon the quantitative analysis of event-related EEG biosignals. Forty participants (twenty-four young, mean age 22 years; sixteen elderly, mean age 70 years) took part in a task that was designed to challenge cognitive flexibility. Elderly participants had slower RTs than young participants, whereas error rates did not differ between the two age groups. The analysis of evoked and induced event-related EEG oscillations rested on Morlet wavelet transformations in the delta-, theta-, alpha- and beta-frequency bands. The analysis of the evoked event-related EEG oscillations revealed more pronounced central delta and theta activity in response to an auditory stimulus in the young compared to the elderly participants. We also observed a crossover interaction with regard to the induced EEG oscillations. Specifically, young participants showed more pronounced event-related alpha-desynchronization at temporo-parietal electrodes during stimulus recognition, whereas elderly participants showed evidence of more pronounced event-related beta-desynchronization at central electrodes during response preparation. These data are discussed against the background of thalamo-cortical mechanisms of the genesis of EEG rhythms. Specifically, process-induced facilitation of posterior thalamo-cortical processing (stimulus recognition) and of anterior basal ganglia-thalamo-cortical processing (response preparation) seem to be age-dependent. Future studies will examine the role of dopamine in these EEG phenomena that are related to the aging of the brain.

Age-related feedback effects on working memory performance and brain activity.

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Working memory (WM) performance declines with ageing due to significant neural decline. The aging process can be counteracted by reorganizing brain functions and changing of cognitive strategies in older people. Feedback (FB) is assumed to help chunking information and facilitating WM performance. Twenty one younger and 21 older employees had to perform a visual 0-back (low WM load -WML) and 2-back task (high WML) with and without FB. Under high WML older adults responded more slowly and less accurately than younger ones. The P3b component was shifted to frontal areas in older adults, while a parietal maximum in younger was found. P3b latency was later in older adults relative to younger adults under high WML. Older adults showed larger contralateral activation and lower ipsilateral inhibition of motor areas than younger adults. The N1 in occipital visual cortex was larger in older than in younger adults. FB facilitated performance under high WML in both groups that were accompanied by different neuronal patterns. In younger adults FB led to shorter P3b latency, while no changes in motor activation was found. In older adults FB did not change P3b latency and delayed motor activation. FB positivity was later in older compared to younger adults. The results suggest that both age group benefit from FB in terms of performance improvement was achieved in different ways. Younger adults seem to implement FB better for chunking information. In this way the categorization process was facilitated and resulted in earlier P3b. In contrast, FB in older adults provokes the adoption of an accuracy-oriented strategy when an impaired categorization process is compensated for by enhanced attention, facilitation the early encoding process and delaying of motor activation. In sum, FB appears to facilitate a reorganization of WM in younger adults and to enhance controlled processing in older adults.

Measuring compensation and its plasticity across the lifespan.

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Two important aspects have to be integrated when studying compensation: (1) the knowledge about specific compensational mechanisms and (2) the consideration of lifelong changes in these mechanisms, i.e., the plasticity of compensation. Accordingly, the present talk addresses the questions (a) which neural networks are supporting successful cognitive performance across development, (b) what are the associated compensational mechanisms and (c) are these compensational mechanisms plastic across the lifespan. To answer these questions, we suggest to integrate behavioural and neuroimaging methods and present specific methods and their advantages and disadvantages. The relevance of this integration will be illustrated by presenting data from our lab using ERPs and (s)LORETA to study compensational processes across the lifespan in a higher order cognitive function, i.e., delayed intentional behaviour. A higher activation in old adults or adolescents in successful trials compared to young adults is considered compensatory as specialized cortical regions are selectively recruited in response to task demands. The findings from our lab suggest that whereas the performance outcome might be the same in different age groups, underlying processes and activations might be fundamentally different. The talk will conclude with a discussion about specific implications of this integrative approach when studying the adaptive potentials and limits of human cognition.

Age-related differences in a driving-like dual task situation.

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Research revealed age-related deficits in visuo-motor dual tasks. Car driving can be taken as a related practical example. By means of behavioural- and EEG-data we investigated central processes in young and older participants during a driving-like dual task. Participants performed a primary tracking task and a secondary visually cued attention task. In the visual attention task under dual task condition, the older vs. young participants showed generally higher response times, however, comparable error rates. In addition, they improved their behavioural performance more than the younger participants. A higher CNV amplitude of the old vs. young group between cue and stimulus suggests that the older invested more ressources to the dual task in this interval. By means of sLORETA the age-correlated amplitude difference can be explained by higher activation of the older vs. young participants in right parietal, bilateral frontal and postcentral areas as well as in the precuneus. The tracking error of the older vs. young participants was generally increased, and relatively more increased after relevant targets in the attention task. In contrast, their tracking error relative to their individual tracking performance was even lower compared to the young group in the cue-stimulus interval. Possibly, the older use the invested ressources in this interval not only to prepare for the following stimulus, but also, to meet the task requirements of the tracking task in the difficult dual task situation. In sum, older participants were able to improve their performance in some aspects of the dual task by means of practice and effort. Nevertheless, the dual task situation can lead to a performance decline in the tracking task especially after relevant targets in the secondary attention task. The results bear practical relevance e.g. for the design of information and assistence systems for older drivers.

Simultaneous wavelet analysis of EEG-channels.

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One-dimensional wavelet analysis allows for the processing of single channels only. Hence, any suspected connection between channels has to be analysed either before or after the transform for every pair of channels, making the analysis very cumbersome at times. Matrix-wavelets, however, provide a novel means for the analysis of vector-valued signals, i.e. of several channels at once, and can even be parametrised so as to take into consideration the relations between channels. While the computations employed in the method are very intricate, they are hidden from the user, and in the standard case all information contained in the data is preserved during the transform. This allows any abstraction from the data to be pushed to later stages in the analysis, making the analysis more robust to unobvious errors, for example incorrect indexing. We present first results illustrating how the choice of parameters can influence the reduction of dimensionality based on PCA.

Sparseness in space meets sparseness in time: EEG sychronization is associated with fMRI resting state networks.

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FMRI resting state data display several sets of co-activated brain regions (so called Resting State Networks; RSNs). EEG resting state data show a limited set of highly synchronized scalp field patterns, suggesting transient phase-locking of distributed cortical patches (Koenig, 2005). We investigated whether the known fMRI RSNs coincide with EEG-fMRI

BOLD correlates of specific patterns of phase-synchronous EEG. Combined resting-state 96-channel EEG and 3T-fMRI was recorded in 14 healthy young subjects. fMRI RSNs were identified by an ICA. The EEG was analyzed using a) a global frequency domain measure of synchronization (GFS) and b) wavelet analyses combined with spatial clustering to identify transiently oscillating synchronous EEG states (microstates). GFS and microstates dynamics were used as regressors on the fMRI signals to identify their BOLD correlates. Those BOLD correlates were then compared to the previously identifed RSNs. GFS BOLD correlates in lower alpha (8.5-10.5Hz) coincided with the Dorsal Attention RSN, while GFS BOLD correlates of the upper alpha band resembled the Default Mode Network. The dynamics of different microstate classes were also associated with the Default Mode Network, a network associated with frontal attention and self-reference, and others. Conclusions: Specific patterns of common-phase EEG oscillations are associated with specific patterns of fMRI co-activation during rest. This supports the hypothesis that the different modules of widespread neuro-cognitive networks observed during rest (and obviously also during task execution) are coupled through a transient phase-locking of their oscillations.

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EEG source localization differences between adult and pediatric realistic head models.

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Even if individual MRI data and digitized electrode positions are unavailable, realistic head models yield more accurate source localizations than spherical shells [1]. In this contribution, source localization differences between adult realistic head models derived from the ICBM-152 geometry [2] and pediatric head models derived from the MNI-175 geometry [3] are elaborated. The respective roles of head shape and skull conductivity are quantified.

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Pinprick-evoked potentials: Correlate of positive symptoms in nociception.

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To date, nociceptive pathways can be functionally evaluated using laser-evoked potentials. However, these signals are sensitive to detect lesions by means of neurophysiologic deficits (reduced or delayed amplitudes), whereas an objective measure for plus-symptoms like mechanical hyperalgesia is missing so far. Here we describe a novel technique, pinprick-evoked potentials (PEPs), which may close this clinically important gap. PEPs were elicited by mechanical stimulation using a flat-tip probe (diameter 0.25 mm, force 128 mN), which activates A-delta nociceptors, and is frequently used to clinically assess mechanical pain sensitivity. A trigger output enabled us to average the responses time-locked to the onset of the mechanical stimulation. PEPs were recorded in 10 subjects during stimulation of the right and left hand dorsum before and after intradermal injection of capsaicin into the right hand, which experimentally induces mechanical hyperalgesia in the skin surrounding the injection site. PEPs in response to stimulation of normal skin were characterised by large biphasic negative-positive (NP) complex, maximal at the vertex, with the N and P waves having approximate latencies of 100 ms and 220 ms, and amplitudes of 5 V and 12 V, respectively. All subjects developed mechanical hyperalgesia following capsaicin injection. Stimulation of the hyperalgesic skin resulted in a significant N amplitude increase (+63.4%, p=0.02, one-sample t-test). The increase of the P wave was not significant (+15.3%, p=0.10). In one patient with a high spinal lesion and reduced unilateral pain sensitivity below the lesion, standard SEP were normal and symmetric, whereas PEP amplitudes as well as laser-evoked potentials were reduced on the symptomatic side. These results indicate that PEPs (1) primarily reflect cortical activities triggered by somatosensory input transmitted in A-delta primary sensory afferents and spinothalamic projection neurons, and (2) represent a useful tool to explore experimentally-induced secondary mechanical hyperalgesia.

Contact cool and heat-evoked potentials - CEPs and CHEPs - are mediated by distinct A-fiber classes.

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Perception of non-painful cold stimuli and of pricking pain plays an important role in quantitative sensory testing (QST) as parameters for A-delta-fiber function. Since QST depends on active participation of the patient, objective tests for A-delta-fiber function are also needed. Whereas laser-evoked potentials (LEPs) and contact-heat evoked potentials CHEPs have been validated, no such test exists for the thermoreceptive pathways for cooling. Evoked potentials elicited by a contact-thermode stimulator (CHEPS, Medoc Ltd.) were recorded from scalp electrodes. Cool (by -3 deg C) and heat stimuli (by +16 deg C) were directed bilaterally to the hand dorsum of 12 healthy volunteers from a baseline temperature of 35 deg C in 16 blocks of 20 stimuli each (ISI 8-10s). Subjective heat pain/coolness of each stimulus was subjectively rated using a numeric rating scale. Mean heat pain ratings were 23.1 (SD 6.3), cooling was not perceived as painful, mean coolness ratings were 3.4 (SD 3.0). Preceded by a small negativity (N1), the evoked potential for both stimuli consisted of a vertex negativity (N2) followed by a positivity (P2). Peak amplitudes did not differ between cool and heat evoked potentials (15.99 (SD 2.06) V versus 19.17 (SD 2.27 V; p>0.05). Latencies were shorter with cooling than heating (N2 323 vs 397ms, t-test; p<0.01). Heat pain ratings steeply decreased initially (tau1 about 15 s) and leveled out thereafter (tau2 about 88 s), cool ratings dropped very slowly (tau>2000s). Local desensitization with 10% capsaicin creme for >24 h completely abolished both, heat pain and CHEPs but did not reduce subjective coolness and CEPs. These data indicate that both stimuli elicit similar vertex potentials via activation of distinct A-delta fibers. Peripheral adaptation to cool stimuli is less pronounced than to heat. Combining CEPs with CHEPs could be used as objective method to examine somatosensory pathways in more detail.

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Mapping the cortical correlates of acoustic lateralization with Near-Infrared Spectroscopy.

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Interaural time differences (ITD) are major cues for the spatial perception of sound sources. In normal hearing subjects, binaural presentation of acoustic stimuli leads to a shift of sound perception to either left or right side, depending on the degree of time difference (lateralization). There is growing evidence that the processing of acoustical stimuli is organized in a cortical dual pathway system in which certain areas are responsible for the processing of qualitative stimulus properties whereas other areas are involved in the processing of spatial information. During the localisation of sounds fMRI studies show activation of the inferior parietal cortex and the superior frontal sulcus. However, an objective measure of spatial hearing ability is needed for patients that cannot be easily assessed in the scanner (i.e. paediatric patients, cochlear implant users). The aim of the present study was to investigate cortical correlates of lateralization in a group of healthy controls with near-infrared spectroscopy (NIRS) that offers considerable advantages in setting for acoustical paradigms (no scanner noise, no artefacts due to metal implants). 50 adult normal hearing subjects completed a sound lateralization task, where subjects indicated the perceived direction (left, right, frontal) of an acoustic stimulus (100μs clicks or 830ms clicktrains, 50 dB SL) presented via insertable headphones. Simultaneously changes in cortical oxygenation were measured using 2x22 channel NIRS over parietal and frontal areas. Comparing stimuli with large ITD (750 μs) to such with shorter ITD (100 μs) we observed an activation of the left inferior parietal cortex. Thus NIRS seems to be a suitable method to measure the cortical correlates of acoustic lateralization.

Early electrophysiological effects during Stroop tasks – First results.

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According to brain imaging studies, non-compatible Stroop stimuli activate the anterior cingulum of the human brain. In electrophysiological experiments effects on long-latency components (400-800 ms) are stressed. We investigated 16 adults who processed compatible and non-compatible color words which were presented on a monitor. Presentation was randomized, and stimuli occurred in the center, or in the left or right visual field. EEG was EEG was recorded from 30 channels located between the inion and 5Between 80 and 140 ms latency there was a significant interaction between compatibility and visual field location (F(2,30) = 3.89, p < 0.05), and between 150 and 250 ms component latency was higher with compatible than with non-compatible stimuli (F(1,15) = 4.55, p < 0.05). The third component occurred between 250 and 350 ms latency, but it showed no significant effects. Spatial PCA resulted in four components that explained 78.6% of the variance. Factor scores were employed in discriminant analyses in order to identified experimental conditions. For ERPs elicited by central stimuli, at 110 ms latency 75Our results show how the compatibility of Stroop stimuli is reflected in field strength and topography as early as at about 100 ms latency. In addition to late components reported in the literature there is rapid information processing in primary visual areas during Stroop tasks.

EEG spectral power before and during hypnosis reflects hypnotizability.

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Healthy people volunteering for hypnosis differ in hypnotizability. EEG data that might reflect this predisposition before baseline and during hypnosis were controversial. Our multichannel-EEG study intends to clarify the controversies. 60-channel EEG was recorded from eleven high ('highs') and eleven low ('lows') hypnotizable healthy volunteers comfortably seated with eyes closed. EEG recordings before, immediately after induction of hypnosis, and in deep hypnosis were spectral analyzed (relative power versus average reference) in eight frequency bands. Subjects self-rated their hypnotic depth. T-tests and repeated-measures ANOVAs were applied for exploratory statistics. Before hypnosis, highs and lows showed no significant difference in self-rated hypnosis depth, but for deep hypnosis, highs rated depth significantly higher than lows. Before hypnosis, highs had lower power in the theta and alpha1 frequency bands, but higher power in beta3. Single-channel analyses revealed no differences between hemispheres. The changes of power spectra over the three time points exhibited the following differences between groups: Highs mainly showed an increase in theta power (F=4.48, p=0.03), while lows showed a decrease in alpha1 (8.5-10 Hz) [F=8.64, p=0.01], an increase in alpha2 (10.5-12 Hz) [F=7.13, p=0.005], and fluctuations in gamma frequency (35-45 Hz) power [F=3.89, p=0.04]. Our results agree with earlier reported changes in theta and alpha EEG frequency bands that distinguish low- and high-hypnotizable subjects before and during hypnosis, and that suggest higher arousal in highs before hypnosis.

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Are short reaction times related to frontal midline theta?

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Inconsistent results have been reported correlating EEG parameters with reaction time (RT) (Oken et al. 2006). Due to the fact that attention is a prerequisite for fast reactions and is associated with the frontal midline theta, we investigated this relationship of frontal theta power and RT. 35 healthy subjects (11m, 24 f) performed two visual simple RT-tasks, with either a fixed (4000 ms) or a variable inter-stimulus interval (ISI) (3500 - 5750 ms). Theta frequency was adjusted individually from 6 - 4 Hz below the individual alpha peak frequency (Klimesch 1999). The prestimulus interval (-750 to 0 msec) was divided in 3 x 250 msec segments (t1, t2, and t3). Data were analyzed for 5 midline positions only. RTs below 125 ms or exceeding 1000 ms were excluded, and short/long RTs were divided according to the individual median RT. A four factorial ANOVA including the factors PERFORMANCE (fast/slow), TASK (fixed vs varying ISI), TIME (t1, t2, t3), and LOCATION (Fz, FCz, Cz, Pz, and Oz) was conducted. Besides significant main effects for PERFORMANCE, TIME and LOCATION as well as several 2-factorial interactions, the most interesting finding was a significant interaction of TASK x PERFORMANCE x TIME. While for varying ISI thetapower remained unchanged over time and performance, in the fixed ISI condition thetapower increased from t1 to t3. Interestingly this increase was more pronounced for fast RTs. These results can be interpreted in a way that, while with varying ISI the subjects are unable to prepare correctly for a fast response, this is possible for a fixed ISI. In addition, if in the fixed ISI condition, prestimulus thetapower is increased, fast responses are more likely as compared to trials with lower power.

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EEG power spectra, LORETA areas and self-rated headache pain.

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How is the subjective intensity of headache reflected in EEG power spectra, and where in the brain is the origin? In 16 migraine patients (without aura, 6 medicated; mean age 38.3 years, SD=7.7; 12 women), we recorded 19-channel EEG during initial resting (4 minutes) on an attack-free day. Patients visual-analog self-rated headache intensity. On average/patient, 65.6 s artifact-free EEG was available. For each of the eight independent EEG frequency bands, means of spectral power across channels (absolute and relative), and LORETA functional images (absolute and relative voxel strength) were computed, and correlated with subjective headache intensity. The correlations were negative ($p<0.1$) with absolute power in the delta, alpha2, beta1 and 3, and gamma bands, but positive ($p<0.1$) with relative power in delta and beta2. Absolute LORETA voxel strength (corrected for multiple testing $p<0.1$) correlated negatively in all bands but delta; relative voxel strength correlated positively with delta through alpha1. Negative correlations with absolute LORETA strength concerned only left anterior voxels in theta and alpha1, only left-hemispheric in beta1 and beta2, predominantly left in alpha1 and beta3, but more right in gamma; all positive correlations with relative strength were right anterior (delta, theta and alpha1). Medicated and unmedicated patients showed agreeing tendencies. Thus, with increasing headache intensity, EEG absolute power decreased, localizing in the left hemisphere (some frequency bands predominantly anterior), while relative strength increased exclusively right anterior. The results suggest that increasing headache intensity is associated with increasing left- hemispheric anterior-weighted activation.

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Time course of mental calculation processes: a combined fMRI and MEG study.

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The issue of how arithmetic operations are represented in the brain has been addressed in numerous studies. Lesion studies suggest that a network of different brain areas (e.g. the left and/or right parietal lobe, frontal cortex, and basal ganglia) is involved in mental calculation processing. Neuroimaging studies have reported inferior parietal and lateral frontal activations during mental arithmetic using tasks of different complexities and using different operators. There is, however, scarce information about the time course of sequential activation of the different brain regions involved in mental arithmetic. The present study investigated fMRI-BOLD and event-related MEG activity during addition, subtraction, multiplication and division performance in tasks of differing in complexity. Tasks were presented both auditory and visually in two different runs within one session. Modality of stimulus presentation resulted in substantially different BOLD activation patterns. Data showed activation patterns in prominently right frontal, parietal and subcortical regions when contrasting complex and simple calculation tasks. Preliminary findings demonstrate different task-related spatio-temporal characteristics of dipole wave forms as revealed by seeded dipoles based on fMRI activation foci. However, as large variances in single trial based data analyses suggest individual different time courses of activity during complex mental calculation, it is suggested that MEG data, obtained during complex mental processing, should better be analysed on a non-averaging-based single trial level considering potential individual differences in task-related oscillatory brain activity and variations in timing of mental processing of cognitive sub-components.

Gender related differences in visual processing.

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The aim of the present study was to investigate gender related differences in brain activity for tasks of verbal and figural content presented in the visual and auditory modality. Thirty male and 30 female respondents solved 4 tasks while their electroencephalogram (EEG) was recorded. Also recorded was the percentage of oxygen saturation of hemoglobin (%StO2) in the respondents? frontal brain areas with near-infrared spectroscopy (NIRS). The main findings of the study can be summarized as follows: (1) Most pronounced differences between males and females were observed for the factor modality - visual/auditory. (2) Gender related differences in neuroelectric brain responses could be observed during the solution of auditory and visual tasks, however on the behavioral level only for the visual tasks did females display shorter reaction times than males. The ERP amplitudes of the early evoked gamma response, P1, and P3 were higher in females than males, whereas the N4 amplitude was higher in males than females. The differences were more noticeable in the visual modality. The NIRS showed a more bilateral involvement of the frontal brain areas in females as compared with a more left hemispheric frontal activity in males. In the task conditions an increase in right hemispheric activity in females was observed, however this increase was less pronounced in the visual than the auditory domain, indicating a more lateralized processing of visual stimuli in females. Taken all together the results suggest that the females' visual event-categorization process is more efficient than in males.

Event-related alpha oscillations related to perception, sensorimotor processing and response inhibition in elderly.

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A major challenge for developmental cognitive neuroscience is to understand how changes in cognitive functions related to aging are associated with changes in the neuronal information processing architecture. Previous studies on EEG event-related brain oscillations suggest functional changes in alpha-bands with age during sensory and memory tasks. The topographical distribution of both single trial lower and upper alpha magnitude and the corresponding phase coherence is documented to be altered in elderly persons. Thus, alpha oscillations, not only associated with sensory, but also with sensorimotor functions may be altered with age. Thereby, compensatory mechanisms, possibly reflected in increased frontal alpha synchronization, may be of profound relevance. The present study investigates age-related differences in the modulation of alpha oscillatory activity related to sensory and sensorimotor functions, including response preparation, execution, and inhibition. EEG was recorded while ten young and ten elderly persons performed a visual evoked potential (VEP), a cued stimulus response (S-R) and a cued visual Go/NoGo task. Early event-related synchronization (ERS, 0-250 ms) and late event-related desynchronization (ERD, 200-600 ms after stimulus onset) of single trial lower and upper alpha was analysed using poststimulus amplitude enhancement and inter-trial phase coherence measures. The results show comparable modulations of lower (8-10 Hz) and upper (10-15 Hz) alpha activity in young and elderly related to the sensory and different forms of motor response processing. Specifically, less upper alpha ERD at central locations and reduced early lower alpha ERS characterized response inhibition processing in both age-groups. We discuss the counter-intuitive, hypothesis that reduced efficacy of some basal neural inhibitory mechanisms could enable older observers to perform better than or comparable to younger persons on tasks using large, high contrast checker board stimuli. We conclude that observation of alterations in alpha oscillatory networks with age may depend on the stimuli applied.

Error-related components and impulsivity reflected by trade-off between speed and accuracy.

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We examined a neurophysiological aspect of the impulsivity as defined by performance. First, we selected 71 participants from a group of undergraduate and graduate students. They performed an arrow version of flanker task and were classified into 3 subgroups by determining RT and the rate of incorrect response: the impulsive group (+1 SD above average or higher in incorrect response rate), the average group (+1 SD below average or shorter in RT and lower in incorrect response rate) and the remaining group. Next, the flanker tasks were administered to 7 participants from the impulsive (6 male and 1 female) and the average group (5 male and 2 female) during EEG recordings. We consistently confirmed that individuals in the impulsive group had shorter correct RT and higher incorrect response rate for incompatible stimuli compared to individuals in the average group. Furthermore, double-error rate was significantly higher in the impulsive group than in the average group. We found two clear GFP peaks following response in both groups, and these components were identified as ERN/Ne and Pe. Although the value of GFP showed no difference in both groups, the amplitude of ERN/Ne at Cz was significantly lower in the impulsive group as compared to the average group. In scalp field topography, we noticed that the negative centroids at ERN/Ne peak was central area in the average group while it was more anterior area in the impulsive group. Psychophysiological data showed lower ERN/Ne activity over central area in the impulsive group. These results suggest that the inability to adjust behavior underlying impulsivity is associated with the ERN/Ne activity.

Training in breath counting is reflected by EEG power and LORETA functional images.

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Does breath count training alter brain electric activity? Breath counting is a basic exercise for meditation. Since meditation has been suggested as migraine treatment, we wanted to determine whether breath count training affects brain activity assessed with EEG. On attack free days, 19-channel EEG were recorded from 16 migraine patients (mean age 38.3 years, SD=7.72; 12 women) during initial resting, breath counting (repeatedly count one to ten for 5 minutes) and final resting, all with eyes closed. Seven of these patients were assigned to do one month of breath count training; thereafter, all EEG recordings were repeated. EEG was spectral analyzed versus average reference; mean relative power across channels was computed in the eight independent frequency bands. EEG-LORETA funtional imaging was used to localize changes observed in the head surface EEG recordings. ANOVA's (2 sessions x 2 conditions x 2 groups) for the 8 frequency bands revealed no main effects, but an interaction (p=0.058) in the theta frequency band. In this band, post-hoc tests showed, during the second session, a significant power increase from initial to final resting only in the trained group. LORETA functional tomography revealed that the observed differences consisted in significantly (corrected for multiple testing) increased voxel strength in left parietal areas. In sum, state-dependent learning effects were observed in the EEG after one-month training of breath counting: these effects occurred not in the resting state, but in the state immedialy after having completed a breath count exercise.

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Neurofeedback for children with attention deficit / hyperactivity disorder (ADHD): Clinical and neurophysiological results of a randomised controlled trial.

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Neurofeedback is a neuro-behavioural, computer-assisted training which could become an important treatment module for children with attention deficit/hyperactivity disorder (ADHD). In a multisite randomised controlled study, we evaluated clinical and neurophysiological effects of a neurofeedback training compared to a control training. 102 children with ADHD (age: 8 to 12 years) participated in the study. They either performed a neurofeedback training or a computerised attention skills training (randomised group assignment). The training programs comprised 36 sessions within two blocks of about 4 weeks each. The neurofeedback training consisted of both a theta/beta training and a slow cortical potentials (SCP) training. Pre-training, intermediate and post-training assessment comprised several behaviour rating scales (e.g. the German ADHD rating scale, FBB-HKS) and neurophysiological measurements (EEG, event-related potentials). For both parent and teacher ratings, the neurofeedback training was superior to the control training. The effect size was .60 for the FBB-HKS total score (parent ratings, primary outcome measure). In the resting EEG the neurofeedback group showed a reduced theta activity after the end of training. In addition, EEG measures recorded at baseline as well as changes of EEG parameters from pre to post training were related to the clinical outcome. Furthermore, SCP training was associated with an increase of the contingent negative variation in a cued attention test. Contrary to our expectations no increase of the P300 amplitude was found for the theta/beta training group. Neurofeedback can be considered as a clinically effective method for the treatment of children with ADHD. The neurophysiological effects could reflect correlates of a successful training. Future studies should examine how to optimise a neurofeedback training and how to integrate it into a multimodal treatment program for children with ADHD.

Gevensleben H, Holl B, Albrecht B, Vogel C, Schlamp D, Kratz O, Studer P, Rothenberger A, Moll GH, Heinrich H (2009): Is neurofeedback an efficacious treatment for ADHD? A randomised controlled clinical trial. J Child Psychol Psychiatry, 50: 780-789.

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Effects of SMR and sham neurofeedback on EEG amplitude.

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During the last few years several studies have shown that humans are able to modify their own brain rhythms by the means of neurofeedback (NF). Besides the meanwhile established use of NF in therapeutical settings as for the treatment of ADD/ADHD or epilepsy, the effects of NF in healthy subjects are less clear. Especially for healthy subjects, there is a lack of empirical data focusing on the effects of NF on the EEG. Although there are several reports indicating that subjects are able to learn to increase the amplitude of the sensorimotor rhythm (SMR; 12-15 Hz), there are almost no studies describing the concomitant effects on a resting EEG preceding and/or following NFT. In the reported study 12 healthy subjects received visual feedback of the SMR while the 8 subjects of the control group received feedback from several varying frequency bands (pseudo-neurofeedback PNF). Both groups performed 25 NF-training sessions (5 weeks with 5 trainings) and were instructed to increase the power as depicted by an in- or decreasing circle. EEG was recorded at C3 and C4 during the training as well as in resting conditions preceding and following each NF session. The results indicated that, during training, SMR amplitude significantly increased in the experimental group, whereas it remained unchanged in the PNF-training. However, this increase in SMR amplitude was present only during the training. Interestingly there was also a strong tendency towards increased SMR amplitudes during the eyes open condition.

Project ADHD & EEG-Neurofeedback Therapy (PANther).

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Attention Deficit Hyperactivity Disorder (ADHD) affects approximately 4% to 12% of all school-age children. Primary treatment for ADHD is medication, although 30% of children fail to respond to psychostimulants. Findings from previous studies suggest that electroencephalography (EEG)-neurofeedback training is a promising alternative treatment for ADHD. However, few studies evaluated the effects of neurofeedback treatment in comparison with a control treatment that corrects for expectancy effects and other unspecific factors. This project involves a double-blind, randomized, placebo controlled study in 120 children with ADHD (8-15 years) with as main objective to examine the effects of EEG neurofeedback in ADHD on clinical symptoms of ADHD and cognitive functions, controlling for unspecific treatment effects. A secondary objective is to examine the underlying mechanisms of EEG neurofeedback. ADHD children will receive 30 sessions of personalized EEG neurofeedback or sham feed back (i.e., feedback based on a simulation signal). Prior to and after treatment, rating scales will be filled out, neuropsychological measures will be administered, and EEG and (f)MRI measurements will be performed. So far, 15 children participated in this study. Preliminary findings of pre- and post assessments will be presented. Since it is a double-blind study, the preliminary results will be presented without differentiating between groups. Our study with a double-blind, randomized, placebo controlled design will make a novel contribution to the literature about the effects of neurofeedback in ADHD. Moreover, the acquisition of MRI and EEG data before as well as after neurofeedback/sham training may give more insight into the mechanisms underlying EEG neurofeedback.

ADHD Neurofeedback Research Network Symposium: Preliminary tomographic neurofeedback results from children with ADHD.

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In an ongoing study tomographic neurofeedback (NFB) is evaluated to improve treatment of attention deficit hyperactivity disorder (ADHD). Children with ADHD are trained over 18 sessions (36 units) in twelve weeks to regulate their brain activity (EEG frequencies and slow cortical potentials) in the anterior cingulate cortex (ACC). Thirty-one-channel electroencephalogram (EEG) is used to calculate low-resolution electromagnetic tomographic (sLORETA) NFB. All training sessions start with a baseline resting EEG, which is analyzed for spectral power tomography focusing on theta and beta frequency bands. We hypothesized that region specific NFB training leads to a continuous decrease of theta/beta ratios, reflecting an increasingly attentive resting EEG in the target region across training sessions. Preliminary analysis of 5 children (age: 10-13 years) show a decrease of theta/beta ratio in the ACC over the time course of the whole training. Linear regression is significant across the training sessions for the group mean, and individual regression slopes tend to be negative across subjects. These results suggest that tomographic NFB helps normalising estimated intracerebral activity in a specific brain region affected in ADHD.

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Announcements — Ankündigungen

- **ISBET Meeting**

  The annual meeting of the *International Society for Brain Electromagnetic Topography (ISBET)* will take place as a Joint Meeting of ECNS / ISBET / ISNIP in Istanbul, Turkey from September 14 to 18, 2010.

  Information and Registration at: `http://www.ecns2010.com/`

- **Deutsches EEG/EP Mapping Meeting (DMM)**

  Das *19. Deutsche EEG/EP Mapping Meeting* findet vom 15. bis 17. Oktober 2010 in Schloss Rauischholzhausen statt.

  Angenommen werden freie Beiträge zu Themen der hirnelektrischen Aktivität des Menschen in Form von Vorträgen oder Postern.

  Schwerpunkte

  - Professor Dr. Silvana Galderisi (Napoli) "The renascence of the electrophysiological methods in schizophrenia research"
  - Workshop Dr. Thomas Koenig (Bern) "Tutorial zur Datenanalyse mit Ragu (RAndomization Graphical Userinterface)"

  Information und Anmeldung unter: `http://www.med.uni-giessen.de/physio/`