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Virtual Meditation:
Comparison of the Effects of Meditation and Neurofeedback on Cognitive Processes

2009 Lukáš Ondřej

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neuropsychologie, meditace, neurofeedback, EEG, kognice, pozornost

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„Prohlašuji, že jsem tuto diplomovou práci vypracoval samostatně a výhradně s použitím citovaných pramenů, literatury a dalších odborných zdrojů.“

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Contents

THEORETIC PART

EMPIRIC PART

Abbreviations

3D	Spatial Orientation test
ABP	ambulatory blood pressure
ACC	anterior cingulate cortex
ACT	acceptance and commitment therapy
ADD	attention deficit disorder
ADHD	attention deficit hyperactivity disorder
ACh	acetylcholine
ANOVA	analysis of variance
ANS	autonomic nervous system
ATI	aptitude (attribute) by treatment interaction
B (BA)	Brodmann area
BM,BEAM	Brain Electrical Activity Mapping
BP	blood pressure
C	central area, centrally localized electrode (odd left, even right)
CBF	cerebral blood flow
CNS	central nervous system
CNS	central nervous system
CNTRL	control
CORSI	Corsi Block-Tapping Test
CRH	corticotropin-releasing hormone
CT	computed tomography
Cz	central medial electrode
DA	dopamine
DBT	dialectical behaviour therapy
DLPFC	dorsolateral prefrontal cortices
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders, 4th Edition
EEG	electroencephalography
ESG	electroencephalospectrogram
F	frontal area, frontally localized electrode
FCz	medial frontocentral electrode
FFT	fast Fourier Transformation
Fm	frontal midline
fMRI	functional magnetic resonance imaging
Fz	frontal medial electrode
GABA	gamma-Aminobutyric acid
Glu	glutamate
HF	high frequency
HRV	heart rate variability
LC	locus coeruelus
LF	low frequency
LORETA	low resolution electromagnetic tomography
MANCOVA	multivariate analysis of covariance
MANOVA	multivariate analysis of variance
MBCT	mindfulness-based cognitive therapy
MBSR	mindfulness-based stress reduction
MED	meditation
MRI	magnetic resonance imaging
NCCAM	National Center for Complementary and Alternative Medicine
NE	norepinerphine

NFB	neurofeedback
NREM	non-REM, synchronous sleep
O	occipital area, occipitally localized electrode
OA	oculi aperti
OC	oculi clausi
P	parietal area, parietally localized electrode
PASAT	The Pace Auditory Serial Addition Test
PET	positron emission tomography
PFC	prefrontal cortex
PMS	premenstrual syndrome
PSNS	parasympathetic nervous system
PSPL	posterior superior parietal lobule
Pz	parietal medial electrode
QEEG	EEG curve quantified by analysis
RAS	reticular activating system
rCBF	regional cerebral blood flow
RELAX	relaxation
REM	rapid eye movement, paradoxical sleep
RP	relapse prevention
RR	relaxation response
RR	relaxation response
RT	Reaction Test
SD	standard deviation
SIGNAL	Signal Detection test
SMA	supplementary motor area
SMA	supplemenary motor area
SMR	sensorimotor rhythm
SNS	sympathetic nervous system
SPECT	single photon emission computed tomography
SPL	superior parietal lobule
STROOP	Stroop Interference Test
TM	Transcendental Meditation®
TPR	total peripheral resistance
TRN	thalamic reticular nucleus
V1	primary visual cortex
V1	primary visual cortex
VTA	ventral tegmental area
VTS	Vienna Test System
WSRT	Wilcoxon Signed Rank Test

Meditation

1.1. Towards Definition

Meditation and meditation techniques have throughout history always been connected to mysticism and religion. Considering the diversity of religious practices around the world, their philosophical and cultural relationship, it is not surprising to find the term ‘meditation’ employed in a highly imprecise sense such that its descriptive power is greatly decreased. Consequently some authors speak of term’s inadequacy and argue its irrelevance in neurosciences (Lutz, Dunne, & Davidson, 2007).

Indeed, there is an evident bias to interchange meditation with other epithets (e.g. relaxation), but mostly these attempts to categorize various practices beneath the same diagram reflect some intellectual tendencies in the early 20th century, especially perennialism[1]. In science such a position becomes particularly problematic with demand of test verifiability of the hypotheses. Other aspect of this recognition of the particularity of contemplative traditions is related to advances in the neurosciences (specifically the knowledge of cognitive and affective processes) over the past decades. Various mediation techniques may arouse specific responses and therefore activate specific neural circuits. Hence, a more detailed and profound approach, which reflects the minute characteristics of the technique in concern, is required. However, some authors (Fontana, 2007), even though acknowledging the differentiations among the diverse forms of meditation, recognize the necessity to emphasise the common features, which according to them often outweigh the discrepancies. This second standpoint concentrates on mutual aspects but sometimes may incline to dismiss important circumstances and draw general conclusions.

These two positions constitute the basic inconsistency in the study of meditation, so typical for exploration in the social sciences in general. First is an understandable reaction on the extreme reductionism and deficiency of quantitative investigations parallel to the rising influence of qualitative research. The second represents a more balanced access to those specifics, which qualitative methodology cannot ever achieve. Moreover, we can conclude that meditation practices have lost shade of mysticism that had often concealed their important features from Western scientific tradition. Important factors are that meditation is more and more practised in the West and also that there is a sharp rise of neuropsychological studies in the East where meditation is considered more traditional. Analogically to incrementing number of studies on the topic and rising knowledge of meditation, the quality of research designs and methodology is likely to escalate. As Shapiro (1984) states, there has

[1] **Perennial philosophy** (philosophia perennis) is notion of the universal recurrence of philosophical insight independent of epoch or culture, including universal truths on the nature of reality, humanity or consciousness (anthropological universals). The term was popularized in more recent times by Aldous Huxley in his 1945 book: The Perennial Philosophy. The epithet remains in the use in philosophy of some Neo-Thomist authors, but has otherwise mostly fallen from favour (wikipedia.org).

been dramatic increase in the number of empirical literature, which is methodologically more sophisticated and goes beyond the easy research constructs of the pioneering years.

Nevertheless, the problem remains if one is to define ‘meditation’ in the context of neuroscientific study, for a great variety of techniques, practices and activities to which the term might refer or be applied to. Correspondingly with the progress in the study of meditation a change in the epithet’s application is notable. Tendency to use the term in an overall sense is being abandoned in the favour of more precise and detailed description when defining the object of scientific study, as demonstrated by Lutz et al. (2007). Though, especially in the application of meditation form in psychotherapy we may still observe disregard for the whole context of the technique in focus and oversimplification of its incorporation in the therapeutic process (e.g. Parez-de-Albeniz & Holmes, 2000). The complex and multifaceted intervention, which meditation represents in its mixture of specific and incidental elements, makes it often challenging to discern its specific effects; to standardize, quantify, and authenticate them for the research purposes, as well as for its application as an intervention programme (Caspi & Burleson, 2005). For the reasons mentioned we can hardly find definitions that would sufficiently describe all the elements which form meditation in all its complexity. The conceptualizations from early research period are clearly insufficient and incomplete and do not meet criteria of up to date accuracy. Present day definitions specify the term meditation operationally, listing the different parameters it should contain. Together with Cardoso et al. (2004) we will understand ‘meditation’ (1) a specific technique (clearly defined), involving (2) muscle relaxation somewhere during the process and (3) logic relaxation (no analysing, no judging, no expecting) and a necessarily (4) self-induced state, using a (5) self-focus skill (archor).

1.2. Classification

There are different ways to classify meditation forms. A very common is categorization based on the background of religious and philosophical tradition from which they descend (Hinduism mediation techniques, Christian practices, New Age meditations, etc.). This approach however doesn’t help to constitute inspectional summary desirable in sciences. To put forward classification acceptable from the positions of neuropsychology, one should accent those aspects which are related to the fundamentals of the discipline. Generally distinguished are *Western* and *Eastern* meditation forms which have many specifics of their own. In the Western spiritual tradition meditations are tightly connected to the three dominating monotheistic religions and from the same perspective were also considered the Eastern meditation techniques. However, there is an immense difference between the two traditions. In the first – the Western tradition, meditation was a part of complex spiritual practices and rituals, which were associated on the basin of some central point; while in the Eastern tradition meditation was a more autonomous, often constituting the central position of the religious practices and often having secular contexts, such as martial arts. This fact became to be recognized from the 1970s when the first studies on the health benefits of mediation started appearing and mediation was dissociated from the religious background.

Both the Eastern and the Western techniques can be classified according to processes of awareness and focus of attention, on concentration mediations and mindfulness meditations, although the latter are more typical for the Eastern religious, especially those outgrowing from Hinduism. The *concentration* forms are used almost universally in religions and spiritual practices. During this type of meditation a practitioner focuses attention on a single stimulus, or invariant group of stimuli, such as the breath or the rise and fall of the diaphragm (Dunn, Hartigan, & Mikulas, 1999). As the meditator plays active role in the use of attentional resources, this form of meditation is also called active. *Mindfulness* can be defined as allocation of attentional resources among all origins of stimulation. Awareness is not focused on any single object but is specified rather by receptivity to all stimuli, while their evaluation is repressed; therefore some authors prefer to use term receptive meditation. Farthing (1992) characterizes mindfulness as deatomization of perception. Mindfulness meditation can also be described as a form which focuses on the field and concentration meditation as a technique which focuses on a preselected specific object within the field; and still there exists variety of methods which shift between the field and the object (D. H. Shapiro, Jr., 1982). Attentional processes of mindfulness and concentration meditation thus represent two poles of continuum rather than discrete categories and can be likened to perception of Gestalt ambiguous figures which illustrates fluctuations in field-object (figure-ground) in an effective means (Martin, 1997). Using attentional mechanisms as the basis of definition Shapiro (1982, p. 6) states that "meditation refers to a family of techniques which have in common a conscious attempt to focus attention in a non-analytical way and an attempt not to dwell on discursive, ruminating thought." The basic features and differences of mindfulness and concentrative form are summarized in Table I.

Receptive Meditation	*Concentrative Meditation*
Sustained attention, *un*focused and inclusive	Sustained attention, focused and exclusive, aided by intention
An open, universal awareness; more formless	A more one-pointed attention; more formed
Gentle, employing a light touch	More forced, deliberate
Notices when attention strays	Holds attention fixed
Not cultivated by struggle	Requires willpower
A simple noticing of anything, distracting or otherwise	Works best in an environment free from distractions, physical and mental
Can shift into introspection and comprehension	Comprehension is not a necessary accompaniment
Several approaches, translated as bare attention, mindfulness, insight, just sitting, Vipashyana, etc.	Several approaches, translated as the path of the absorptions, samadhi, the "vision quest," etc.

Table I The basic features of mindfulness and concentration meditation (Austin, 2006, p. 30).

Another possible classification of meditation techniques is their division between *meditation with ideation* and *meditation without ideation* (in the term ideation we understand imagination). The Western tradition has focused on the first type and has developed prayers and spiritual exercises based on the core of ideation. The meditator bears an idea or group of ideas in the forefront of awareness and stimulates his intellectual activity. Quite frequently the ideation gains form of visualization and often evolves into complex and detailed system, such as contemplations developed by St. Ignatius Loyola[2] or Vajrayana[3] tantric practices of Tibetan Buddhism. In meditation without ideation, the meditator's goal is to divert attention from processes of cognition and reach state of contentless awareness of the mind (Fontana, 2007). For the character of the methods described it is obvious that concentration meditation is connected to ideation and mindfulness meditation is without ideation.

Mikulas (1990) proposed division of meditation into four components – form, object, attitude and behaviours of mind. Those which vary the most among different techniques are form and object. *Form* refers to the setting where meditation occurs and the practices which one does with one's body while meditating. There is a wide variety of methods in some of which the body is immobile (zazen[4]), in others it is let free, some techniques such as Yoga, Tai Chi or Qi-gong involve physical movements, and still in others the person participates in daily activities while meditating (A. B. Newberg & Lee, 2006). Founded on Osho's division we can distinguish active (or dynamic) and passive meditation techniques. Active meditation refers to those techniques in which one's body isn't assuming static posture. *Object* refers to the primary attentional target during meditation. *Attitude* can be described as mental set in which one approaches meditation and is considered to be an important factor affecting behaviours of mind during meditation (Mikulas, 1990; Dunn et al., 1999). *Behaviours of the mind* are strategies used to change one's awareness of internal or external stimuli (Mikulas,

[2] The **Spiritual Exercises** of Ignatius of Loyola, (written within 1522-1524) is a brief set of meditations, prayers and mental exercises, designed to be carried out over a period of 28 to 30 days; Written with the intention of enhancing and strengthening one's faith in a manner that has distinctly Roman Catholic aspects, Ignatius' Spiritual Exercises present God and the Devil as an active players in the world and its reflection in the human psyche. The main aim of the Exercises is to develop "discernment" within human psyche, the ability to discriminate between good and evil spirits. Discernment is achieved in order to act "with the Grace of God." This is the context within which, during the exercises, one thinks about humility, selflessness for the sake of the religious life, and reflection upon natural sin. There is an important acknowledgment that the human soul is continually drawn into two directions: both drawn towards Godliness, and at the same time tempted towards baseness. Accordingly the Exercises provide several illustrations of how one might best be able to refrain from satiating one's lower desires and instead how one might find a means to redirect inner energies towards the fulfilment of higher purpose in life (wikipedia.org)

[3] The goal of spiritual practices within **Vajrayana** tradition is to become Buddha by a being that compassionately refrains from entering nirvana in order to save others. It is based on the concept of *upaya* which emphasizes that practitioners may use their own specific methods or techniques in order to cease suffering and introduce others to dharma – the "higher truth" or ultimate reality of universe. This accelerated path to enlightenment is achieved through use of tantra techniques based on visualization and esoteric transmission of certain accelerating factors directly from teacher to student (wikipedia.org)

[4] In Zen Buddhism is **zazen** (literally seated meditation) the primary method of meditation. The term refers to the posture which aim is to calm the body and mind and experience insight into the nature of existence and thereby gain *satori* (enlightenment) (Austin, 2006).

1990). Attention can be directed outward and inward or in diverse combinations of the two. In some techniques (Zen) are the attentional capacities focused on eternal or ultimate sources and are connected to changes of consciousness and traits of behaviour (Austin, 1999); in terms of energy we may divide the techniques into upward meditation which draws energy upwards and ultimately draws consciousness out of the body and causes psychological dissociation, and downward meditation which brings the energy into the body, usually with the hearth or third eye as the focus. Apart from the attentional component of receptiveness Bishop et al. (2004) propose experience-orientation element which leads to insight into the nature of one's mind and adoption of de-centred perspective.

J. P. Miller (2006) categorizes meditation according to four different types: *intellectual* meditation (e.g. vipassana, focus on awareness and discrimination), *emotional* (e.g. mantra, connection with the heart), *physical* meditation (e.g. Tai Chi, involvement with various forms of movement), and *action-service* (e.g. Karma Yoga, each act is an offering to the divine).

There are other possible ways to categorize meditation practices, based on different aspects of techniques. When we consider the multifaceted character of meditation, we may end up with tens of different classifications. However, those mentioned here are probably also those most agreed and widely recognized.

1.3. Methodological Challenges

Research on meditation is mixed and of questionable quality. Most of the studies are methodologically flawed, with insufficient number of cases, lack of standardized diagnostic procedures and are limited to non-psychiatric populations (Atkinson et al., 1996). At present there are only few well-designed studies on meditation, many studies in the area suffer from lack of an adequate control group, small sample sizes, inadequate evaluation of the integrity of the treatment and unmeasured compliance (Allen, Chambers, & Knight, 2006).

As mentioned above, meditation has many different aspects which should be considered before designing and analyzing research. Studies of meditation can be grouped into two main categories based on their overreaching goals; therefore every study should be designed to specifically aim the underlying question of interest (Caspi & Burleson, 2005). The classical *efficacy-effectiveness* research model tests meditation against some recognized comparator, with the intention of assessing its relative efficacy and effectiveness for given conditions. The most common form of design is in this case comparison between groups; second possible form is within a subject comparison made in the same individuals in different conditions. The *explanatory* research model focuses on identifying the mechanisms that are related to meditation; that is, to determine how meditation works and to discover its biological mechanisms and neurological correlates. The explanatory approach measures physiological changes that meditation produces immediately or consequently.

Whichever model is conducted there are methodological challenges of such type that research design must thoughtfully consider key aspects of meditation that are currently unknown or uncertain (Caspi & Burleson, 2005). The most cited examples are the length and frequency of meditation practice necessary to achieve results, and whether meditation effects are linear or cumulative and for which conditions this applies. Also, as different meditation techniques produce diverse physiological responses it is probable that one technique may produce different intersubject responses (Maupin, 1965; Blackwell et al., 1976). If this hypothesis regarding individual variability is indeed true, as the most recent findings confirm (Murata et al., 2004; Takahashi et al., 2005), than another methodological step is estimation of the most appropriate ways to address the strain between standardizing the intervention protocol, which would back internal validity, and individualizing it to support external validity (Caspi & Burleson, 2005). Aptitude (or attribute) by treatment interaction research (ATI) offers solution to this problem by proposing a design which systematically considers individual characteristics in the procedure of intervention evaluation. The paradigm is based on the conception that aptitude or attribute (A), it is every individual characteristic or variable, may moderate (I, interaction) the treatment (T) effects on an outcome (O) (Shoam & Rohrbaugh, 1995).

$$A \xrightarrow{I} T \longrightarrow O$$

Caspi & Burleson (2005) suggest that the best approach to avoid the trap of false causality between the aptitudes and treatments is *a priori* explication of the plausible aptitudes with following confirmatory testing, rather than exploration *post hoc*. According to their solution of methodological problems in the meditation research the design should incorporate these features (Caspi & Burleson, 2005):

- Better matching among the research question, the goals of the study, and the design chosen, especially as related to subject eligibility criteria and the choice of the comparator.
- Clear explication of the particular meditation technique to be used in the study, with due consideration to issues related to standardization vs. individualization.
- Monitoring and assessment beyond the descriptive level of compliance of the issues related to meditation integrity and fidelity (i.e., the quality of meditation achieved as a self practised technique) that may have an impact on therapeutic effects.
- Examination of individual differences across subjects using the ATI approach, in order to gain knowledge that can be used to better match individuals and treatments, thereby maximizing treatment safety, efficiency, and effectiveness.
- Integration of qualitative methods into quantitative clinical studies to achieve more robust and enriched methodology.

1.4. Health Benefits

Based on early articles and books of 1970's the dominant view of meditation in non-traditional Western conditions reduced its effects on a type of relaxation. Benson et al. (1974) practically devalue meditation techniques on 'relaxation response' (RR), stress and tension relieve program, which characterize (Benson, 2000) as "a physical state of deep rest that changes the physical and emotional responses to stress [...] and the opposite of the fight or flight response." Thus RR is a learned behaviour or practice describing a natural restorative phenomenon that is common to all as a counterbalancing mechanism to the fight-or-flight response recognized in 1915 by Walter B. Cannon. It is a state of profound rest that can have lasting effects if any of a number of techniques that involve mental focusing is practised regularly.

Based on this presumption, it is not surprising that meditation has become one of the many ways to teach clients to relax and reduce anxiety. According to Dunn et al. (1999) this position is curious though if one considers the research results achieved during the same time period and contrasting Benson's influential contribution. In a series of EEG studies was meditation (concretely Transcendental Meditation® (TM)[5]) distinguished from commonly encountered states of consciousness, such as wakefulness, sleep, and dreaming, and from altered states of consciousness, such as hypnosis and autosuggestion (Wallace, 1970); EEG records from meditators practicing TM made distinction between the meditative state and other states of consciousness (Banquet, 1973); the state of 'pure consciousness' as an outcome of meditation was clearly discriminated from other states of consciousness (Badawi et al., 1984). These studies revealed the uniqueness of consciousness of meditation and suggested that meditation was fourth state of consciousness.

Hence, the first health benefits recognized as an effect of TM were related to Benson's RR: decrease of heart rate and blood pressure, diminished respiratory rate and lower pulse rate, decreased oxygen consumption and muscle tension, decreased blood lactate, reduction of cortisol and noradrenaline. Application of meditation and identification of its benefits were studied especially in the context of cardiovascular and respiratory function (Badawi et al., 1984; Wenneberg et al., 1997; Barnes, Treiber, & Davis, 2001), anxiety, stress and increase of positive affect (Kabat-Zinn et al., 1992; J. J. Miller, Fletcher, & Kabat-Zinn, 1995; Teasdale, Segal, & Williams, 1995; Teasdale et al., 2000). Number of studies were also dedicated to pain management in the patients with chronic pain symptoms (Kabat-Zinn, Lipworth, & Burney, 1985; Kabat-Zinn et al., 1986), influence of meditation on immune function (Solberg, Halvorsen, & Holen, 2000; Davidson et al., 2003), treatment of insomnia (Woolfolk et al.,

[5] **Transcendental Meditation® (TM)** was derived from Vedic tradition and introduced by Maharishi Mahesh Yogi in 1958. The technique is practised in sitting position with one's eyes closed, twice a day for the period of 20 minutes. It does not involve concentration or contemplation but aims to settle down one's awareness to experience a state of restful alertness. With the deep body relaxation the mind transcends all mental activity to experience the simplest form of open awareness called "transcendental consciousness."

1976; Khalsa, 2004) and physical or emotional symptoms that may be related to chronic illnesses and their treatment (Speca et al., 2000).

The benefits of meditation, even though related, are for simplicity often divided into three groups: *physiological* (e.g. decreased hypertension and cholesterol), *psychological* (decreased anxiety, improved self-concept), and *behavioural* (decreased stress or use of tobacco). Meditation effects became soon linked together and it was clear that some of them have common origin; as an example of such factors may serve serotonin production which can be increased by meditation, low levels of serotonin are associated with depression, obesity, insomnia and headaches (Murray, 1999). In the following phase was research oriented on connecting health benefits and discovering mutual factors, especially on physiological, chemical and molecular basis. Benson's relaxation response was put in a larger physiological context with the addition of nitric oxide as a molecule involved in this learned response (Stefano et al., 2000; Stefano, Fricchione, & Esch, 2006).

Proliferation in the investigation of meditation was stimulated with the technological progress in medicine in the recent years and the development of new imaging techniques which better explain or disprove some of the mechanisms of meditation. Currently the most promising research approach to meditation seeks the significant changes in the brain functioning which is believed to account for many of the outcomes.

1.5. Adverse Effects

The application of meditation and its incorporation in various therapeutic and intervention techniques is on the rise mainly in the recent years, together with incorporation of new and alternative treatment methods in the compound system of healthcare. The view of meditation has changed from the primary reductionism to relaxation to conceptions of omnipotent techniques, which are often applied in an erroneous manner and without considering possible risks. Meditation was traditionally exercised by very few; it wasn't even practised by the majority of Buddhist monks for which represents the central point of religious experience. It was never meant for many, nor was it ever considered safe for the majority of people.

The research on meditation side effects and risks is founded basically on self-reported evidence given by meditators and in many cases also appears as a co-product in the search of possible health profits; many studies have format of case report. Although the self-report assessment methods seem psychometrically promising, with great internal consistency, they are developed exclusively to explore facets of meditation (Baer et al., 2006), particularly in mindfulness which popularity has been growing in the recent years. Side effects and adverse effects from meditation are still out of focus and accordingly there is a considerable lack of reliable literature on meditation risks. This situation is somewhat paradoxical if we reflect upon the fact that Easter schools of thought widely warn of the difficulties of following a spiritual path, but is still comprehensible when we think over the separation of body-mind unity in the context of Western dualism and detachment of meditation from its philosophical framework.

Adverse effects can be grouped into two categories in relation to the moment of their occurrence. Some outcomes may be present directly during the process of meditation while others may manifest themselves just after practising or after some lapse of time. Shapiro (1992) found that 62,9% of her 27 subjects reported during and after meditation at least one side effect and 7,4% even experienced profound adverse effects. The length of practice seems irrelevant to the quality and frequency of the adverse effects which Shapiro summarizes – induced anxiety, tension increase, loss of motivation, depression, boredom, pain, impaired reality testing, confusion and disorientation. Otis (1984) in his classification of side effects of TM includes also procrastination, antisocial behaviour and decrease in tolerance of other people. In both studies the meditators also reported felt addiction to meditation. That is, when quitting meditation practising the exacerbation of various symptoms was observed.

Craven (1989) describes such side effects as mild dissociations, feelings of guilt and psychosis-like symptoms; hallucinations and dissociations from reality as a consequence of meditation were also reported in several case studies (French, Schmid, & Ingalls, 1975; Trujillo, Monterrey, & Gonzáles de Rivera, 1992; Sethi & Bhargava, 2003). Along with derealization was confirmed that meditation can also provoke depersonalization (Castillo, 1990) and precipitate mania (Yorston, 2001). Kuijpers et al. (2007) gives an extensive overview of mediation adverse effects together with review of studies and case reports and concludes that “meditation may induce serious psychological side effects, including depersonalization, derealization and psychotic symptoms like hallucinations as well as mood disturbances” (p. 461).

With regard to possible vulnerability factors for the occurrence of meditation-related psychotic episodes, there is an increased risk in individuals with psychiatric symptoms in their anamnesis and in person with certain personality structure. There is also risk in the cases of sleep and sensory deprivation, and physical exhaustion, as demonstrated in several case studies (Chan-ob & Boonyanaruthee, 1999; Sethi & Bhargava, 2003). However, various deprivation practices may in some techniques form an important component of meditation process and can be in fact the path towards the goal of meditation itself. The meditative trance experience among Indian yogis is often characterized by dissociation, hallucinations, and believes in possessing supernatural powers. While in Western cultures are such experiences typically labelled pathological, in some Eastern spiritual traditions may be viewed as an important part of spiritual awakening (Castillo, 2003).

Normally have meditation-induced psychotic episodes short duration and are characterized by a mixture of psychotic and affective symptoms. There is a wide range of meditation methods which were confirmed not devoid of such episodes. Lu and Pierre (2007) document psychotic episodes associated with Bikram Yoga[6], a culture-bound syndrome induced by traditional Chinese medicine meditation practices Qi-gong is listed both in the Chinese Classification of Mental Disorders and DSM-IV under name Qi-gong Psychotic Reaction and is characterized as “an acute, time-limited episode characterized by dissociative, paranoid, or other psychotic or non-psychotic symptoms [to which] especially vulnerable are individuals who become overly involved” in Qi-gong (*Diagnostic and Statistical Manual of Mental Disorders*, 2000); the same reaction to overt exercise in vulnerable individuals may also occur after Tai Chi practice, which shares essential parts with Qi-gong (Ng, 1999). Well documented is also Kundalini Syndrome, which could be characterized as a set of sensory, motor, mental and affective symptoms, reported predominantly among people who have had a near-death experience, and which is also attributed to Yoga meditation practitioners[7]. In Zen have been psychotic episodes well documented for centuries and are known as *makyō* which is defined as being the combination of *ma* (devil) and *kyo* (objective world) and is translated as ‘ghost cave’ or ‘devil cave.’ Makyo refers to chimera, illusions or hallucinations which are believed to lead to a demonic state and can be mistaken by the practitioner for kenshō (seeing the true nature), the experience of enlightenment (Kapleau, 1967/1980). Austin (1999, p. 373) contradicts Shapiro (1992) with regard to the relevance of the length of practice and states that “the side effects of meditation tend to stop when each meditative period is shortened, and will fade when meditation is practiced regularly over a period of months to years.” Otis (1984) concluded that also TM was not free of side effects and that patients experienced more adverse effects if they already had psychiatric disorders. There are accounts of adverse effects associated with mindfulness practice in historical writings. Such records recognize that adverse events may be provoked by excessively intensive meditation, particularly without proper or adequate preparation. Cited symptoms include problems with pulse, heart and back pain, and general feeling of nervousness, restlessness, and irritability, visions, ringing in the seemingly out-of-body experiences, and/or insomnia (Allen et al., 2006). Traditionally recommended treatment for such problems might include rest and quiet, a break from meditation practice, walks and specific dietary advice (Berzin, 2002).

As documented, in the wide range of meditation techniques, no matter of what origin, historical context and philosophical tradition, we encounter side effect which may be risk to psychological health as we perceive it in our Western clinical tradition. Lot of the demonstrated symptoms seem alike among diverse meditation techniques and we can

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[6]**Birkam Yoga** also known as *Hot Yoga* was developed by Birkam Choudhury. It utilizes 26 yoga postures and 2 breathing exercises in a heated environment (105˚F/40.5˚C) with humidity level of 40%. A dynamic yoga session at such temperature promotes profuse sweating which should rid the body of toxins. The temperature also warms the body which facilitates its flexibility (wikipedia.org).

[7] However, some authors claimed that there was tendency of health professionals to ignore or pathologize religious and spiritual issues brought into treatment and that there was need of new category which would reflect the religiosity gap between clinicians and patients and would be sensitive to cultural differences (Lukoff, Lu, & Turner, 1992). Such category entitled religious or spiritual problem was included in fourth edition of DSM under Other Conditions That May Be a Focus of Clinical Attention (Turner et al., 1995)

presume that they have common origin, just as well as there are some shared elements concerning the health profits stimulated by meditation practice. Based on the studies on side effect in meditation we can conclude that there exist some personal predispositions to development of psychotic episode induced by meditation.

1.6. Meditation in Therapy

From the introduction of Benson's RR there has been a remarkable growth in the use of meditation in psychotherapy. In the first stage was this interest more theory-driven, oriented on the potential use of meditative practices in the therapeutic process (Murphy & Donovan, 1983; Bogart, 1991). However, in the past two decades there has been rise in practical utilization of meditation techniques in therapy and modification of different meditative practices for therapeutic purposes.

Deatherage (1975) studied the effectiveness of meditation as a primary and secondary therapeutic technique with a variety of psychiatric patients and conceptualized meditation as a cost effective self-treatment regimen that helps understand own mental processes and allows to gain self-observing distance which is necessary for the ability to control them. Carpenter (1977, p. 403) concludes that "meditative and esoteric traditions have much to offer to psychotherapy [because] they provide different perspective on the common therapeutic goals of changing the relationship of the individual to himself and changing the relationship of the individual to society." He suggests that the efficacy of meditation in therapy is due to a combination of relaxation and training of the central nervous system (as introduced by Benson), and cognitive and attentional restructuring through self-observation and insight. Also Shapiro and Giber (1984) examined two main hypothesis regarding the meditative self-regulatory mechanisms which benefit therapy, relaxation and global desensitization are attempting to explain meditation effectiveness in reduction of fears and phobias and referring to insight and cognitive refocusing, while altered state of consciousness is working through changes in attitude and perception. Also many other authors of this time have seen the potency of meditation in the possibility to observe and categorize mental events and subsequently to gain insight which is allowing one to step out of conceptual limitations and stereotyped reactions and behaviors" (Bogart, 1991, p. 386). Hence, the meditation is viewed as a type of introspection which enhances the quality of therapy by the process of self-exploration and which saves therapist's time. This *synergistic approach* intends to combine meditation and therapy which are perceived as technically compatible and mutually reinforcing (Kutz, Borysenko, & Benson, 1985).

However, with regard to meditation adverse effects and vulnerability of some individuals to meditation-induced psychosis we must consider this approach is rather naive. As emphasize Shapiro and Giber (1984) meditation cannot be simply prescribed as an energizing element to psychotherapy without a previous selection of patients; the therapist should be very considerate when incorporating meditation in the therapeutic process. They noted that the positive effect of meditation had been documented in several studies on its short-term application and in several studies on perceptual and behavioural improvement, concretely on self-concept and perceived behavioural change. Nevertheless, they pointed out the methodological weaknesses and suggested guidelines for future meditation research: "Because of the excitement and aura of mystery currently surrounding the technique of meditation, there is a tendency to let enthusiasm replace methodology. However, we believe that [...] it is possible to design clinically oriented research studies that provide relevant information about the efficacy of different types of meditation strategies, for specific types of population, with specific concerns" (D. H. Shapiro, Jr. & Giber, 1984, p. 68). The efficacy of meditation was also questioned by other theorists of the time who pointed that there was no clear evidence that meditation was in and of itself therapeutic and that the critical therapeutic variables underlying meditation could be others than the exercise itself. Smith (1984) discusses possible intervening variables in the meditation efficacy and suggests that expectation of relief and regular practice of sitting quietly are factors which are commonly not controlled in studies on meditation effectiveness.

Some authors disagreed about the propound interactive concept and stressed that the goal of meditation (illusion of the self) was irreconcilable with the therapeutic aim of facilitating development of cohesive ego (Bogart, 1991). In a study on compatibility of psychotherapy and Buddhist meditation Bacher (1981) suggested that *sequential approach* when psychotherapy precedes meditation is more beneficial than blending of the two. According to his model it is important to respect individuality in the development of the person; disidentification from emotional and egoic concerns produced by meditation can undergo only those who are personally fully developed.

Bogart (1991) concludes that meditation as a multidimensional phenomenon can be useful in psychotherapy in a variety of ways. First possible application he finds in physiological relaxation and utilization of meditation in alleviation of stress, anxiety, and other physical symptoms. Secondly, meditation can bring about cognitive shifts applicable to behavioural self-observation and management, self-limitations and realization of pathological processes in cognition. Third use may permit thorough access to the unconscious as depicted in psychoanalytic therapies, and meditative insight into unconscious conflicts. In some cases meditation may be compatible with psychotherapy and can be effective in promoting its aims; in other cases it can be strongly contraindicated and may endanger the therapeutic process itself.

Traditionally the most studied and applied meditation techniques have been transcendental meditation and methods based on mindfulness, particularly mindfulness-based stress reduction (MBSR). National Center for Complementary and Alternative Medicine (NCCAM) recognize their positive effects and support supplementation of the two into therapeutic process.

Usefulness of MBSR as an intervention is suggested for a broad range of chronic disorders, and clinical and nonclinical problems (Grossman et al., 2004). The value of mindfulness training is accepted especially for clients treated in individual psychotherapy for symptoms of depression and anxiety; in addition to helping reduce psychological distress, MBSR may increase practitioners' sense of agency and self-directedness, and therefore, the utility of the technique as an adjunct to more traditional psychotherapy is supported (M. Weiss, Nordlie, & Siegel, 2005). Baer (2003) distinguishes between interventions that are based on mindfulness training (MBSR and mindfulness-based cognitive therapy (MBCT)) and interventions that to some extent incorporate mindfulness training (dialectical behaviour therapy, acceptance and commitment therapy and relapse prevention). However, there is an argument whether mindfulness actually furnishes therapy with unique elements or simply accents some of its components. Therefore, there is a need of further study on suggested beneficial effect, especially dismantling and randomized controlled studies are necessary to further support and elucidate these findings. In particular it is important to isolate the active ingredients in the interventions and to identify mechanisms of action (Roemer & Orsillo, 2003). Also other authors criticize insufficient knowledge about the mechanisms of mindfulness and the reliability of effects it is supposed to produce; nevertheless, the quality of methodology and design of both the research and the clinical application has been improving, and the future of mindfulness as an intervention program is considered rather optimistic and is being viewed as a promising enrichment of therapeutic interference (Kabat-Zinn, 2003).

If the popularity of mindfulness meditation among researchers is in the recent years on the rise, the focus on TM has been enormous ever since its introduction in 1958. In fact, transcendental meditation practically aroused the scientific interest in meditation. However, during the following years TM has become a phenomenon that arises many questions. The technique was trademarked and thanks to ingenious strategy of its founder spread around the world. Now the official transcendental meditation website claim over six million followers and support positive effects of TM in over 600 scientific studies which were published in a collection of 6 volumes in Scientific Research on Maharishi's Transcendental Meditation and TM-Sidhi Programme (Yogi, 2007). However, this amount is misleading as many of the articles are simply review papers, theoretical papers, or even science-fiction vision. The actual number of studies published in peer-reviewed journals is only 150 and there is a question of how many can actually be considered valid and not trivial (Coppola, 2006). Among the benefits of TM as described by the official website we can find also "creativity and IQ increment and use of hidden brain reserves"(MVED, 2007). There is no wonder that many of the positive findings and effects of TM are regarded by scientific community rather untrustworthy. The most critical studies on the effects of transcendental meditation are traditionally published in Germany, where the movement was in the ruling of the highest federal administrative tribunal, the Bundesverwaltungsgericht on May 24, 1989 labelled psychogroup" and is considered to be a sect or cult. Couple of German government-granted studies acknowledged that TM can cause psychic defects or destruction of personality” (*The Various Implications Arising from the Practice of Transcendental Meditation: An Empirical Analysis of Pathogenic Structures as an Aid in Counseling.*, 1980; *Final Report of the Enquete Commission on "So-called Sects and Psychogroups" New Religious and Ideological Communities and Psychogroups in the Federal Republic of Germany*, 1998). It is necessary to emphasize that TM is only one of the techniques which have common origin in Vedic mantra tradition, however, is the most wide-spread and logically the one most studied.

The interest in alternative medicine is increasing in the recent decades, partly due to unbearable costs of western medical interventions, partly for their insufficiency. There is no surprise that different national health systems have been incorporating alternative approaches and slowly begin to regard them as equal or even superior to traditional medical treatments. The research on meditation as one such method is likely to accelerate and bring forward incorporation of meditation into therapeutic process. Sceptics point out that “current evidence for the therapeutic effectiveness of any type of meditation is weak, and evidence for any specific effect above that of credible control interventions even more so [and that] the only safety issue seems to be in seriously disturbed patients, in whom meditation may trigger psychotic episodes” (Canter, 2003, p. 1050). Others see promising future of meditation as a psychological intervention, but also multitude of possible clinical applications for health purposes, and finally its use for overall well-being. “Whereas therapy traditionally focuses on the individual's problems and attempts to construct a healthier self-image, a meditatively informed therapy would promote realization of the transience and insubstantiality of all identity constructs as well as the cultivation of equanimity, compassion, and friendliness toward oneself and others” (Welwood, 1983, p. 49).

Physiology of Meditation

2.1. Meditating

As there are so many ways, it is difficult to describe a generic process of meditation. Two different techniques, though common in origin and sharring mutual features, may yet vary in small aspects which may have crucial consequences. As an example can serve the huge amount of techniques arising from Hinduism, in which only slight alternations may evoke distinct physiological responses. As the two techniques most studied for possible therapeutic use are based on mindfulness and concentration, we will further direct the general components which are specific for each method and the features they have in common.

Some of the general meditation facets we may borrow from research of psychedelics. The resulting effect of psychedelics consists of three factors – set, setting and substance (Strassman, 2001). *Set* is related to ourselves, our personal characteristics, and instant and long-term anticipations. It is our personal history, presence and prospective future, our interests, thoughts, habits and sensations. *Setting* applies to the surrounding and environment in which a drug is applied. The process of psychedelic session can be affected by things such as if we are inside or outside, in nature or in a city, by the quality of air and people which are present. Hence set and setting can modify the resulting effects of s*ubstance*. The same schedule we can apply to process of meditation, replacing substance with *technique*[8].

Concentration mediation is characterized by attention focused on a single object or invariant group of stimuli such as breathing, mental visualization of an image, or real image you look at, such as candle flame[9] or a sacred icon. The most common example of concentration meditation is TM technique which is based on repetition of mantra. Examples of religious mantras include a Jesus prayer in the Christian tradition, the holy name of God in Judaism, or the Aum (pravana) mantra in Tibetan Buddhism. As a mantra can serve whatever neutral or meaningless phrase, word or sound, however some may prefer real meaning.

Meditation starts with right meditating position. Most practices prefer sitting position which was proved to be ideal for the right flow of energy in body. In Yoga there is explicitly restricted to practise when lying and the system of meditative positions (sitting postures) is by far the most elaborated. Right position help induce physiological body response (see Physiological Changes, p. 18). The ideal, recommended meditation posture has seven features (Ribush, 2000):

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[8] In fact, diverse techniques may induce activation of different physiological processes and arouse various brain regions and divergent electrochemical responses; therefore the parallel between technique and substance is more then appropriate.

[9] **Trataka** meditation technique, or candle flame gazing, is one of Yoga meditation methods when the sight is concentrated at some external object, often candle flame. Internal imagination of the object is also common.

1. Sit cross-legged on the floor, preferably in the full- or half-lotus position, with a cushion beneath your buttocks.
2. Keep your back straight, with your vertebrae one above the other like a pile of coins.
3. Keep your shoulders level and parallel with the floor.
4. Hold your arms slightly rounded and away from your body, with your hands in your lap, palm upwards, right on top of the left, tips of the thumbs touching.
5. Bend your neck slightly forward, with your chin tucked in a little.
6. Close your eyes lightly or open them slightly, with your gaze down the line of your nose.
7. Also close your lips and teeth lightly, with the tip of your tongue touching the roof of your mouth just behind your top teeth.

When seated comfortably, the meditator should concentrate on the breath, the physical sensation the breath makes as it enters and leaves the nostrils (breathe-in, breathe-out). The breath shouldn't be forced but natural, only observed. Soon, as attention starts to drift away from the breath, the meditator needs to refocus on it. The basic principle on concentrative meditation lays in the deliberate concentration and refocusing of attention on the stimulus.

Receptive meditation forms the central role in the teaching of Buddha where the correct or right mindfulness[10] is essential factor in the path to enlightenment and liberation. The core of right mindfulness is to bring one's attention at the present moment, and by enduring in it the practitioner begins to apprehend both inner and outer aspects of reality freeing the mind of continuous judgment. The way to reach such a state leads through constant practice of active meditation and years of practice in mindfulness itself. The therapy-used mindfulness can therefore scarcely achieve the quality of the right mindfulness.

For mindfulness practice there are similar requirements concerning the setting and the posture of meditator as to concentrative meditation. The difference between the two is in the work one does with one's awareness (Table I.) While concentration meditation has clear object of thought (anchor) and meditator leads mind back to it every time it wanders away, in receptive meditation there is no object but emptiness of mind; receptiveness could be also defined as intense awareness of one's thoughts, motivations and actions. Mindfulness differs from concentration in the way that where concentration involves the practitioner focusing the attention on an object, in receptiveness is every aspect of experience welcomed and appreciated. Meditator takes role of impartial observer of everything that passes before his attention. There is no will or intention to be focused, the practitioner stays rather mindful, that means fully awake and aware of what is going on at the moment. The only anchor used in

[10] "Correct" or "right" mindfulness is the seventh element of the Noble Eightfold Path, the way according to teachings of Buddha leads to the cessation of suffering (*dukkha*) and the achievement of self-awakening.

mindfulness is the breath which connects to the present moment, but apart from that, no attempt is made to direct the attention (Rinpoche, 2000).

EEGs clearly differentiate these two basic meditation forms one from another and also show that they both differ from control states of ordinary calm relaxation (Dunn et al., 1999). The possible explanation of the differences is EEGs are explained on the basis of the mechanisms which occur during the two forms. In concentration meditation is attention focused, in mindfulness one quiets his or her mind, while simultaneously is being aware of flow of objects that appear (Mikulas, 1990). Although the two meditative states may be qualitatively different (based on different mechanism), it is still possible that the same attentional mechanism is underlying their different EEG patterns. That is, attention may vary from a tight focus in concentration meditation to wide and diffuse focus in mindfulness (Dunn et al., 1999).

Both meditation forms have some common process features which help bring out physiological changes and which combination differentiate meditation from other states of consciousness:

1. reduction of sensory input (by focusing the senses on meditation itself)
2. removal of mental conditioning (by not giving reason to any sensory input)
3. settling down the breath rhythm
4. concentration and localization of attentional resources inward on the meditative process
5. raised awareness

2.2. Physiological Changes

Scientific studies reveal that meditation produces a specific physiological pattern that involves various biological systems. The most frequently suggested changes meditation produces are metabolic, autonomic, endocrine, neurological, and psychological. The way these mechanisms concur in producing the final pattern of responses is yet unclear. The vast complexity of biological organization indicates that the physiological response to meditation most likely occurs on a multidimensional, interactive basis (D. H. Shapiro, 1980; Shin, 1997). There have been many reviews published that clarify the changes meditation produces in our body; The consensus is that meditation causes *secondary* physiological and biochemical changes that are appropriate to the deepness of relaxation involved (Delmonte, 1985; Austin, 1999)

Relaxation response, the first thoroughly studied physiological rejoinder to meditation, was identified as the counterpart of the stress or fight-or-flight response (or sympatho-adrenal response). Both states are produced as a natural reaction to specific stimuli and are controlled by autonomic nervous system (ANS) which can either mobilize the body for action through sympathetic nervous system (SNS) or pacify the body through parasympathetic nervous system (PSNS).

As mentioned above, the right posture helps bring on physiological body changes which further affect ANS regulative processes. Sitting *asana*[11] position is advantageous because it allows all the physiological activities go on normally (Mandlik, 2008):

1. Spine is erect which helps create proper balance posture for digestive organs, heart and lungs. These vital organs function at optimum level resulting in increased efficiency and reduced stress.
2. To maintain balance in these positions, brain and other parts (hypothalamus, pyramidal tract, extra pyramidal tracts, cochlea, neuro-muscular junctions) have to work less. Gravity and antigravity muscles need not work hard to maintain the pose as the firm triangular base provided by crossed legs reduces the work. Closing the eyes is also possible without loosing the balance.
3. Abdominal muscles, diaphragm and muscles in the chest are stressed to the minimum extent. Production of carbon dioxide is minimized so that process of breathing is minimized and continuous movement of diaphragm and ribs do not disturb the state.
4. The brain and nervous system has minimal stress, so that mind can be peaceful and relaxed and yet alert.
5. There is no danger of falling asleep as in more relaxing supine or lying down position.
6. The pelvic region gets the rich supply of blood; it may result in toning up of sacral and coccygeal nerves[12].

Benson (1974) argued that the specific physiological pattern (RR) is not unique to meditation per se, but is common to any passive relaxation procedure. However, subjects always reported meditational experiences as more profound and enjoyable than control groups practising relaxation (Kohr, 1977), and eventually there was found evidence of difference in EEG studies (Dunn et al., 1999).

2.3. Metabolic and Respiratory System

Benson (1975) documented that meditation produces significantly deeper rest than sleep. This is determined by oxygen consumption which gradually decreases about 8% over four or five hours of sleep, in meditation it drops 10-20% in the first three minutes" (Benson, 1975, p. 64). This finding supported the results of Wallace (1970, p. 167) who had observed oxygen consumption decrease within 5 minutes after the onset of meditation. The O_2 consumption is regarded as a reliable index of physical activity and arousal; it changes rapidly and is

[11] **Asana** is a body position, typically associated with the practice of Yoga, intended primarily to restore and maintain a practitioner's well-being, improve the body's flexibility and vitality, and promote the ability to remain in seated meditation for extended periods (wikipedia.org).

[12] In **Kundalini Yoga** the power source is located in pelvic region. So far there isn't known any research done on association between awakening kundalini power and increased pelvic blood supply during meditation.

controlled by metabolism. During metabolic process is oxygen converted to carbon dioxide (CO_2) which is eliminated by the lungs. Body starving of oxygen doesn't lead to parallel CO_2 reduction, as the cells continue to metabolize the remaining oxygen in the blood, but it causes a decrease in the concentration of oxygen and increase in the concentration of CO_2 in the arterial blood. Wallace et al. (1971) found that during meditation practice is the relative amount of O_2 and CO_2 in the blood (respiratory quotient) constant and therefore that the metabolic changes of meditation have cellular origin in natural reduction of metabolic activity. Some later studies show even greater oxygen consumption drop than Benson. Farrow & Hebert (1982) document breath suspension in TM practitioners which led to oxygen consumption fall of 40% at a 50% decline in respiration rate. Jevning (1983)indicated that much of the whole body decline of O_2 consumption in meditation was due to decreased skeletal muscle metabolism

Murphy & Donovan (1997) analyzed some 40 studies on metabolic and respiratory changes produced by meditation and found that oxygen consumption is reduced during meditation, leading to carbon dioxide elimination; That respiration rate is reduced and minute volume is lowered, and that meditators sometimes suspend breathing longer than control subjects without apparent ill effects. All these studies strongly suggest that meditation lowers the body need for energy and the oxygen to metabolize it, and that meditation can be viewed as a hypometabolic state like sleep or rest with its unique psychophysiological patterns.

2.4. The Cardiovascular System

2.4.1. Heart Rate

Many contemporary studies have indicated that the heart rate (HR) slows during quiet meditation and quickens during active disciplines or ecstatic moments. There have been distinguished excitatory from relaxing forms, associating their effects with ergotropic and trophotropic conditions[13] of central nervous system (Murphy & Donovan, 1997).

Majority of studies confirm the presumption that meditation decreases HR (Wallace, 1970; Lee et al., 2000) while others give evidence contra such generalization and demonstrate the complexity of impact meditation has on cardiovascular functioning. Findings show that different meditative protocols may evoke common HR effect, as well as specific responses and that some meditation techniques (e.g. Chinese Chi, Kundalini Yoga) may actually induce HR (Peng et al., 1999). This 'meditation paradox', when a variety of relaxation and meditation techniques may produce active rather than quiescent cardiac dynamics, was described in several studies (Stancak Jr et al., 1991; Lehrer, Sasaki, & Saito, 1999). The factor

[13] According to **Gellhorn's model**, the system in our body that controls adaptation and development is actually comprised of two complementary (sometimes antagonistic) systems, each of which organizes functions located at every level of the nervous system. *The ergotropic system* mediates fight or flight responses and anatomically incorporates the functions of the sympathetic nervous system, *the trophotropic system* is responsible for regulating the vegetative functions and anatomically incorporates the functions of the parasympathetic system (Shapiro, 1984).

responsible for cardiovascular response of organism is the respiratory pattern of each meditation technique; breathing meditation was recognized the predominant factor influencing blood pressure (BP) and HR (Barnes, Davis et al., 2004). Heart rate variability (HRV) as an indicator of the cardiac autonomic control is measured using two spectral components – high frequency (HF, 0,15-0,50 Hz) which is due to vagal[14] efferent activity and a low frequency component (LF, 0,05-0,15 Hz), due to sympathetic activity. The autonomic status can be modified by combination of increases and decreases in both HF and LF power, which are produced under different respiratory patterns (Raghuraj et al., 1998). There is also some serious evidence that meditation may modify baroreflex sensitivity[15] (Bernardi, Gabbuti et al., 2001; Bernardi, Sleight et al., 2001). Hence it can be concluded that "certain forms of meditation may be associated with activation of selected components of HRV response and perhaps increased baroreflex sensitivity" (Peng et al., 2004, p. 25). In calming forms of meditation such as TM, zazen, or Benson's RR is the average heart rate declined of 7 beats per minute but some authors found average decline among their subject as high as 15 beats per minute (Bagga & Gandhi, 1983).

There is a question, however, if HR patterns during meditation differ from other states. A meta-analysis of 31 studies concluded that heart rate did not significantly decreased during a TM session compared to eye-closed rest (Dillbeck & Orme-Johnson, 1987). Two possible explanations for such findings are, that (1) resting and meditation do both involve sitting with eyes closed and it appears that any differences in mental activity between those two eyes-closed conditions do not appreciably affect heart rate, or (2) subjects with either higher or lower heart rates during the eyes-closed session tend to come to a middle level during TM practice, an observation which still needs to be tested (Travis & Wallace, 1999).

2.3.2. Blood Pressure

Other important changes of cardiovascular functioning are related to blood pressure. There were found differences between BP in general population and TM practitioners and it was suggested that meditation is beneficial especially in long-term perspective, and that meditators with more than five years of experience had a mean systolic blood pressure 7,5 mm Hg lower than meditators with experience shorter than five years (Wallace et al., 1983).

Meditation reduces both systolic and diastolic BP and its positive effects were demonstrated in such early age as 12,3 years (Barnes, Davis et al., 2004; Barnes, Treiber, & Johnson, 2004). The efficiency of meditation is evident particularly in the studies using ambulatory blood pressure (ABP) which has better ecological validity and has been shown to be a better predictor of cardiovascular complications and hypertension than clinic BP

[14] The **vagus nerve** is the tenth of twelve paired cranial nerves, starting in the brainstem (within the medulla oblongata) it extends through the neck to chest and abdomen, where it contributes to the innervation of the viscera (wikipedia.org)

[15] Impulses generated in the **baroreceptors** inhibit the tonic discharge of the vasoconstrictor nerves and excite the vagal innervation of the heart, producing vasodilatation, venodilation, a drop in blood pressure, bradycardia and a decrease in cardiac output (wikipedia.org).

monitoring (Wenneberg et al., 1997). Meditation is commonly applied in the treatment of hypertension and can be combined with traditional anti-hypertensive medication with efficacy equivalent to adding a second antihypertension agent; approximate reductions of systolic and diastolic blood pressure of 4,7 mm Hg and 3,2 mm Hg would be expected to be accompanied by significant reductions in risk for atherosclerotic cardiovascular disease (J. W. Anderson, Liu, & Kryscio, 2008). An important role in the development of essential hypertension[16] has been implicated to peripheral vasoconstriction (i.e., total peripheral resistance, TPR). There was demonstrated that TPR decreases significantly during TM and it is supposed that decreases in vasoconstrictive tone may be the hemodynamic mechanism responsible for reduction of high blood pressure over time (Barnes et al., 1999). Most studies also show that there is a difference in BP response to meditation and relaxation; while BP decreases during meditation practice it tends not to change or increase slightly during relaxation, supporting the claims of physiological difference between the two (Barnes et al., 1999; Barnes, Davis et al., 2004). There is evidence supported by more than 19 studies that patients with moderate hypertension improve with meditation and most of them also indicate that benefits disappear without continued practice. Nevertheless, a therapeutic approach to hypertension involving meditation has been shown to be effective (Patel, 1977; J. W. Anderson et al., 2008)

2.4. Blood Flow Redistribution

Blood circulations, especially in muscle and brain, are closely related to metabolic conditions and are very sensitive and consistent in its response to behaviour (Shin, 1997). Wallace (1970) indicated a cardiac output decrease of 25% but this data was displaced by evidence coming form two studies of Jevnings et al. (1976; 1978) who reported increased cardiac output of 15% and 16%, respectively. Apart from cardiac output they found an average 20% decline in liver blood flow, decreased hepatic blood flow by an average of 34%, an average decrease in renal blood flow of 20% and 29%, respectively; the authors theorized that decreased skin and muscle blood flow was suggested by other, indirect data, and that since cardiac output increases while all measured organ blood flows decrease, it is possible that cerebral perfusion increases markedly during TM. This hypothesis that most of the distributed circulation must be to the brain has been supported by direct estimation of increased relative cerebral blood flow (Herzog et al., 1990-1991; Jevning, Wallace, & Beidebach, 1992; Jevning et al., 1996).

2.5. Neuroimaging

Functional and anatomical neuroimaging techniques have dramatically invigorated the understanding of brain functioning, neurological disorders and their causes, diagnosis and management. Anatomical imaging techniques such as magnetic resonance imaging (MRI) and

[16] **Essential hypertension** indicates that no specific medical cause can be found to explain a patient's condition while secondary hypertension indicates that the high blood pressure is a result of another condition (i.e., is secondary).

computed tomography scanning (CT) are useful for detecting structural changes in the brain. Functional imaging methods such as single photon emission computed tomography (SPECT) and positron emission tomography (PET) have been useful for measuring changes in blood flow, metabolism, and neurotransmitter activity.

Brain activation studies which apply neuroimaging techniques to explore cerebral function during various behavioural, motor, and cognitive tasks generally utilize SPECT, PET, and functional MRI. Especially functional MRI (fMRI) has been extensively developed in the past years and explains high spatial and temporal resolution in measuring changes in cerebral activity. However, not all of these progressive techniques can be used to study meditative states. Functional MRI, which surely would bring desired insight into the neurology of meditation, is impossible to use for the study of meditation because of the noise the scanner produces. In some studies the investigators attempted the use of fMRI, but the meditators normally found it difficult to carry out the meditation practice, with little success when attempts had been made to acclimatize (A. B. Newberg, 2006). Many of the neuroimaging techniques also disallow meditators to engage the posture or position necessary for regular meditation progression, as they are usually constructed for lying position; there is no wonder that many neuroimaging studies rather explore relaxation than meditation. Nevertheless, they still bring beneficial findings which enhance our knowledge on meditation and consciousness.

2.5.1. Cerebral Blood Flow (CBF)

From the EEG studies comes clear evidence that meditation especially activates frontal and central regions. These results were confirmed also in a number of other studies working with neuroimaging techniques and it is clear that frontal cortex plays essential role in the advance of meditation. Apart from increased activity in frontal areas, particularly PFC, there were also demonstrated some decreases in the parietal regions (Herzog et al., 1990-1991; A. Newberg et al., 2001).

In the recent years there was a boom in the brain research using neuroimaging studies. CBF allows better localization of the structures involved in different functions In the recent years there was a boom in the brain research using neuroimaging studies. CBF allows better localization of structures involved in different functions. Modern neuroimaging techniques based on CBF usually have very good spatial resolution but show weaker results in time resolution; on the contrary, some older functional methods based on electrical activity, such as EEG and MEG, have excellent time resolution characteristics but are limited as to their spatial resolution. Dynamic brain imaging techniques scan CBF using various means of recording. PET records brain metabolism using radioactive molecules injected into the bloodstream or inhaled in gas medium. fMRI is much friendlier to organism as it is founded on oxygen metabolism. During increase in functional activity within the brain, the rise in oxygen produced in increased blood flow actually exceeds the tissue’s need for oxygen (Kolb & Whishaw, 2003). As a result, the amount of oxygen in activated area increases.

2.5.2. PET

Herzog et al. (1990-1991) measured cerebral metabolism during Yoga meditative relaxation (rather concentrative form) using PET and found average metabolic increases in several frontal regions (in percent): +0,5% (inferior), +2,74% (intermediate), and +0,07 (superior); average metabolic decreases in three posterior region were -1, 52% (temporo-occipital), -9, 95% (occipital), and -6,3% (superior parietal). The most obvious general trend was toward reduced glucose metabolism in posterior regions of the cortex, bilaterally. The increases in the frontal regions were rather slight when compared with the greater reduction of metabolic rates in the posterior regions. The slight increase in frontal metabolism appeared consistent with the mental effort involved in concentration; the greater posterior decrease was explained by "reduced visual input during meditation, although the eyes remained open" (Herzog et al., 1990-1991, p. 185).

Similar PET study was carried out by Lou et al. (1999), who investigated CBF in nine meditators during Yoga Nidra[17] relaxation meditation. The session was carried out in a sequence of meditative and control conditions, meditation being led by verbal guidance (45 min tape) which induced different stages of meditation:

2.5.2.a Meditation stages 1 and 2

First stage was described as "verbal guidance to the experience of the weight of individual body parts" and started 6 minutes after the initiation of Yoga Nidra; second stage was initiated 16 minutes after the beginning of meditation and was expressed by "verbal guidance to the experience of joy and happiness in abstract form (i.e., not related to external events or facts)" (Lou et al., 1999, p. 100).

These first two PET stages, in the confirmation of results mentioned above, showed major prefrontal increases in cerebral blood flow. Meditation on sensations of weight of limbs and other body parts was supported mainly by parietal and superior frontal activity, more specifically by the right superior and inferior frontal gyri; abstract sensation of joy by left hemisphere parietal and superior temporal (Wernicke area) activity, concretely left inferior frontal gyrus. Contributing to such increased frontal activity might be the nonspecific effects of trying to focus on sensation in various body regions (stage 1), and on abstract feelings of joy during the second stage (Austin, 2006).

2.5.2.b Meditation stages 3 and 4

Third stage, starting 26 minutes after the onset of Yoga Nidra, was depicted as "verbal guidance to the visual imagination of a summer landscape with forests, streams, and meadows

[17] **Yoga Nidra** is a deep relaxation technique also called 'yogic sleep' in which mind and body is at complete rest but with thorough awareness. The meditator becomes a neutral observer who experiences the loss of conscious control and an enhancement of sensory quality. The mind withdraws from wishing to act and is not associated with emotions, or the power of will. The technique falls into mindfulness category.

with cattle.” Fourth stage began at 38 minute of meditation and was defined as “verbal guidance to the abstract perception of the self: symbolized with a golden egg.”

Even during the third stage there were apparent effects of mental effort. During this ‘visual imagination’ stage there was increased activity in the occipital lobe with sparing of the V1 region, and the parietal lobe. In fact, both inferior occipital gyri showed some of the highest cerebral blood flow increases recorded during the entire study. According to Austin (2006) the internal image the meditators were instructed to envision is designed to evoke substantial increases in occipital and parahippocampal blood flow.

The fourth stage of meditation aroused bilateral parietal activity (inferior left lobule and superior right lobule), and activity in the left postcentral gyrus (the primary sensory cortex).

Authors also pointed to a strong bilateral hippocampal activation common to most meditative situations, and activity in parietal and occipital sensory and association regions (except of V1) which was characteristic for combined meditation measurements (meditative state using visualization). Meditation on body parts was found to strongly activate supplementary motor area (SMA), also parietal and occipital activation was noted. During second stage of joy and happiness, activation was almost exclusively limited to the left hemisphere and included Wernicke region; authors assumed that this was due to abstract verbal nature of the task. Third stage was characterized by strong activation of visual cortex, except for the primary visual cortex, and the parietal cortex. Activation of these and adjacent regions had been previously associated with voluntary visual imagery (Kosslyn et al., 1993; Kosslyn, 1994). However, there is a difference in the lack of prefrontal and cingulate activity during meditation, which authors explained by “less volitional, motivational, and emotional control during relaxation meditation.” The condition when meditators were following a tape guiding differed from most studies on meditation where self-initiated and maintained meditation is more common; internally generated words activate the prefrontal cortex while guided word generation does not, so whether or not the PFC is activated during meditation might be explained by the type of approach practitioner uses (A. B. Newberg, 2006). The remarkable lack of activity in V1 might be due to visual awareness which the striate cortex doesn’t take part in (Crick & Koch, 1995; Lamme et al., 2000).

In one of the earliest PET studies of aware relaxation (Austin, 1988/1999) the subject was lying quietly with eyes masked, and ears plugged lightly with cotton, concentrating on the movements of abdominal breathing. There was shown metabolic activity prominent in two of the basal ganglia nuclei, the caudate and putamen, and in the thalamus. In the cortex, activity was prominent over the middle, inferior, triangular, and opercular regions of the frontal lobes, as well as transverse and superior temporal gyrus. There was high metabolic activity in the posterior regions, especially in the innermost depths of the parietal lobe, the precuneus, and in the cuneus, which is located in further in the occipital lobe. There was also found activity in the hippocampus and in the posterior cingulate gyrus. There was noted that the higher activation in the right hemisphere, which was evident especially in the deeper regions of the parietal and occipital cortex, was due to hemisphere dominations. The left hemisphere is presumably dominant for language, and the conditions of the study – a nonverbal state of mental and physical relaxation, of external visual and auditory blockage – were therefore reflected in the final image (Austin, 1988/1999, p. 282).

2.5.3. SPECT

Newberg at al. (2001) realized SPECT study in which they measured regional cerebral blood flow (rCBF) of eight experienced Tibetan Buddhist meditators. The percentage changes between meditation and baseline were compared and correlations between the structures were determined.

The meditators focused their attention on a visualized image and maintained that focus with increasing intensity for approximately 1 h when they signalled the investigators that they were about to begin the most intense part of meditation. This peak experience is described as a “sense of absorption into the visualized image associated with clarity of thought and a loss of the usual sense of space and time” (A. Newberg et al., 2001, p. 114).

The authors found significantly increased rCBF in the inferior and orbital frontal cortices, the dorsolateral prefrontal cortices (DLPFC), the sensorimotor cortices, the dorsomedial cortices, the midbrain, the cingulate gyri, and the thalami. The other regions showed no significant changes in activity. There was found decrease in superior parietal lobe (SPL) which was negatively correlated with activity in left DLPFC ($r=0,76$; $P=0,03$). On the contrary there were found positive correlations between activity in left DLPFC and left thalamus ($r=0,71$; $P=0,049$), and the change in activity in the right DLPFC correlated positively with the change in activity in the right thalamus ($r=0,71$; $P=0,05$).

Based on their findings the authors made several conclusions about meditative practice (Image I.):

1. meditation is associated with increased activity in the frontal areas
2. increase in prefrontal activity joined by decrease in superior parietal lobule (SPL) is connected to visual-spatial tasks (Cohen et al., 1996), in meditation is decreased activity in SPL related to the sense of an altered experience of space
3. increased activity in sensorimotor areas may suggest significant decree of motor activity required to maintain the subject’s posture and there may be at least some form of visual input from the internal images generated during meditation
4. increased activity in midbrain is related to alternation in autonomic nervous system activity during meditation

5. significantly increased thalamic activity is important for the overall complex processes, thalamus activation may reflect its function as a major relay among cortical and subcortical structures
6. significantly different thalamic laterality index in meditators at baseline compared to controls support the idea that meditation may have long-term effect on brain activity

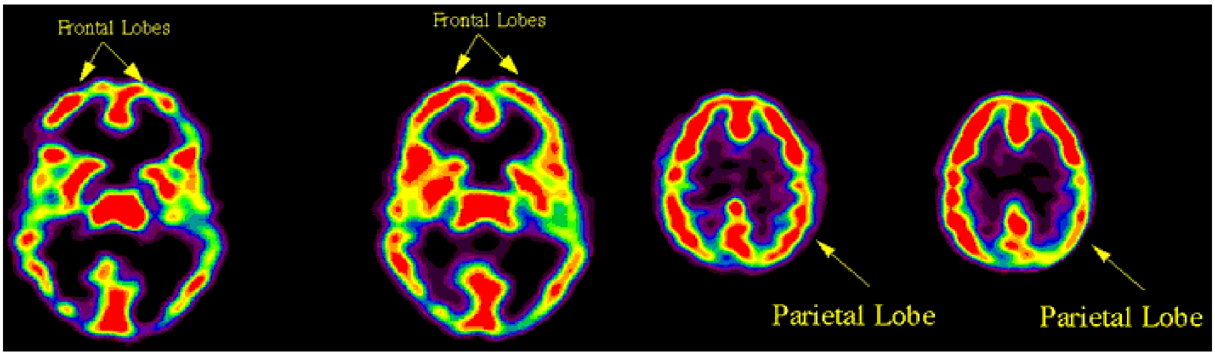

Image I. SPECT images at baseline and during meditation (from http://www. andrewnewberg.com/research.asp)

The study, even though contributing to the knowledge on meditation and pioneering the subject by use of neuroimaging techniques, show many flaws and overlooks or misinterprets data gathered in previous research:

ad 1. The fundamental role of frontal and prefrontal areas in meditation has been well documented in the EEG research and is related in particular to awareness and attention (Banquet, 1973; Klimesch, 1999).

ad 2. Coactivation of prefrontal and parietal areas is related to many executive and cognitive functions, including working memory, motion processing, mental imagery, visual attention, and spatial tasks; therefore, parietal activation is rather general and produced in unison with PFC (Culham & Kanwisher, 2001). It was suggested that "area 5 is the site of higher order processing of somesthetic information received from the lemniscal system, and may give rise to the neural code of position and form of body and tactile objects in 3-dimensional space" (Sakata et al., 1973, p. 85). The hypothesis that decreased SPL activity is related to altered experience of space may be therefore correct; nevertheless, this declination in SPL activity opposed by increment in PFC activity is unusual and should be further investigated. Another possible explanation of such inverse activity of PFC and SPL might be related to visual attention during visualizing meditation.

ad 3. In fact the findings about visual input were previously demonstrated in the study of Lou et al. (1999) where extensive activation of visual cortex was accompanied by increased activity in postcentral gyrus (primary somatosensory cortex); there was shown that activity in sensorimotor areas is modulated by attention to movement (Johansen-Berg &

Matthews, 2002) and that pure sensory input (sensory attention) may interact with motor output (Rosenkranz & Rothwell, 2004). As the increases in sensorimotor areas were especially profound during visualization, the effect of posture maintaining is apparently rather minute when compared to the effect of visual input the meditation may produce.

ad 4. The midbrain, located at the top of the brain stem, is a potent source in the pathway of arousal (Sarter & Bruno, 2000). It is rather obvious than surprising, that midbrain reticular formation affects ANS. High frequency midbrain stimulation leads to cerebral EEG desynchronization (Kaada et al., 1967), while its inactivation, in conjunction with inhibition of serotonin production, guarantee EEG synchronization (Jones, Lawrence, & Bickford, 1983). This slow and synchronized pattern is especially observable up in the frontal and parietal regions, pointing probably on midbrain relays related to visual-spatial attention (Downing, 1988). Yet, midbrain not only activates, but was also found to suppress metabolism. In rat's brain, reticular formation reduces net firing of other cells, including cortical and limbic neurons (Austin, 1999). Hence, the midbrain activation has many possible implications, those attention related being the most pronounced.

ad 5. As the authors conclude, thalamus may be indeed associated with many cognitive and affective responses induced by meditation. It should be noted that thalamus plays important role in the pathways of arousal and that stimulation of some of its parts may even produce EEG desynchronization and light behavioural responses in comatose patients (Austin, 1999), and that "emotional disturbances, such as spontaneous laughing and crying, from thalamic lesions are well authenticated" (Papez, 1937, p. 739). Nevertheless, modern neuroimaging techniques still need to be refined to be able to distinguish among the many nuclei that form thalamus which may act differently during various meditation forms.

ad 6. Again, the fact that experienced meditators show changed baseline activity had been previously documented in a number of EEG studies (Davidson et al., 2003; Lutz et al., 2004). It was suggested that meditation may modulate cortical functioning but doesn't seem to lead to structural changes (Travis, Tecce, & Gutman, 2000). However, some recent evidence proposes otherwise (Lazar et al., 2005).

The study of Newberg and his colleagues has been criticised for reasons concerning the meditation technique. The technique itself wasn't clearly described and some of the arrangements made to adjust it to research conditions were not mentioned even though they might have been crucial for resulting neuroimage. It was noted that the meditators were visualizing with increasing intensity an image into which they were absorbed at the peak stage of meditation, however, the authors did not mention what sort of image was being visualized and which kind of wilfully induced absorption occurred (Austin, 2006). Still more questions arise when we consider that the two cortical regions which showed the highest activation increases (the orbitofrotal cortex 26%, the cingulate gyrus body 25%) were excluded from further analysis, as well as was occipital association cortex. All these regions exhibit fascinating and extensive interactive functions and the explanation of Newberg et al. (2003, p. 117) that they analysed only those regions that "would most likely interact with each other during the task of meditation", seems in this context rather curious. Especially paradoxical is the fact that the analysis didn't include occipital cortex, which in the study of Herzog (1990-1991) showed the greatest relative decrease, and that the authors overlooked the possibility of frontal-parietal interconnection in association to visual processing (see above), when the technique in concern was practically based on visualization.

2.5.4. fMRI

As fMRI is very noisy and the sound the machine produces can be distracting, Lazar and colleagues (2000) hoped to minimize this disadvantage by prehabituating their subjects. Prior to the measuring, their five experienced meditators had been listening to an audiotape where scanner sound was recorded, until they could comfortably achieve a meditative state despite the disturbances of the tape.

The meditators performed a simple form of Kundalini meditation in which they were passive observers of their breathing and silently repeated 'sat nam' mantra during inhalations and 'wahe guru' during exhalations. There was no mention of whether their eyes remained open or closed. There were two 12 min meditation epochs preceded by a 6 min control epoch, hence, two separate time points were available for the analysis (early and late). During the control state the meditators silently generated a random list of animals and did not observe their breathing.

The first analysis compared meditation epochs with control epochs. Significant increases during meditation were found in putamen, midbrain, pregenual anterior cingulate cortex, and hippocampal/parahippocampal formation. Significant activation was also observed in the septum, caudate, amygdala and hypothalamus in at least three subjects. However, the authors admit that "these foci lay too close to areas of potential susceptibility artefacts to be accurately localized and quantified, given our scanning parameters, and so they were not included" (Lazar et al., 2000, p. 1582). The second analysis compared early and late meditation and identified multiple foci of activation in prefrontal, parietal and temporal cortices, as well as in the precentral and postcentral gyri, and in hippocampal/ parahippocampal formation.

During meditation the subjects focus their attention primarily at their breathing, supporting the rhythm by mantra recitation. The authors described this as "a challenging task requiring constant vigilance so that the mind does not wander" (p. 1585). Hence, they hypothesize that meditation will activate the regions and structures involved in attention processing and that the limbic regions probably modulate autonomic output.

The results found in this study help to map the neural structures involved in attention (frontal and parietal cortex) and arousal/autonomic control (pregenual anterior cingulate, amygdala, midbrain and hypothalamus). In addition to these areas there was identified significant activation in the putamen, precentral and postcentral gyri and hippocampus/parahippocampus in a majority of subjects, suggesting that these structures contribute to the meditative stage at some level.

Similar results as those obtained in the study of Lazar and colleagues were reproduced in a study of Buddhist mantra meditation (Hsien et al., 2007). The activation areas of right hemisphere were anterior cingulate cortex (Brodmann area 25, see *Appendix I*) of limbic lobe, middle temporal gyrus (B21), precentral and postcentral gyri (B4&B3), and putamen and thalamus. In the left hemisphere the activations were observed in anterior and posterior cingulate cortex (B24&B29) of limbic lobe, and for two of the three subjects in hypothalamus. It was postulated that activation in many of the areas is connected to cognitive functions, however, it was hypothesized that hypothalamus activation might be related to endocrine secretion.

Another fMRI study (Baerentsen et al., 2001), even though lacking information about meditation technique used, identified several structures which may take part in a hypothesized 'neural switch'[18]. The onset of meditation was characterized by significant activation in left lateral globus pallidus, right inferior parietal lobe and right precentral gyrus (B4&B6), while no significant deactivation were found. Fixed effect analysis revealed significant activations in the left frontal (B11), paracentral (B4), inferior parietal (B40), and lateral temporal (B22) cortex. Activation was also found in the anterior cingulate (B24), hippocampus, and central areas of the brain. Especially prominent were activation in the right temporal lobe (B21), the superior parts of the right gyrus paracentralis (B4&B6) and prefrontal cortex (B10&B11). Significant decreases in activation were observed in the visual cortex (B 17, 18 & 19), especially in the right hemisphere, in the posterior cingulate (B31), parts of left prefrontal lobe (B10), and the right central cortex (B2, B5, B4).

Ritskes et al. (2003) prosecuted research of the hypothesized 'neural switch' and found activation in the prefrontal cortex (gyrus frontalis medius, right side, B10) and in basal ganglia, together with decreases in the gyrus occipitalis superior and the anterior cingulate (B32). It was suggested that "this combination of four events may reveal the neural basis of the experience of enlightenment in Zen [...] where time and place limits have disappeared, and a great feeling of love/unity is experienced" (p. 85 & 88).

[18] Based on previous data from EEG research, which showed that during the first minute of meditation occur rapid shift in physiological functioning, Travis (1999) proposed that there are two complementary neural networks that underlie meditation. One network functioning as a 'neural switch' mediating the shift from normal consciousness to meditation, and the other as a 'homeostatic threshold regulation mechanism' sustaining restfully alert state of mind.

2.5.5. Putting It Together

Esch (2004, p. 10) concludes the findings of various neuroimaging studies of meditation in a general statement saying that "With regard to the CNS, the RR [understand relaxation response] activates areas in the brain responsible for emotion, attention, motivation, and memory (e.g., anterior cingulate, hippocampal formation, amygdala) and may also serve the control of the autonomic nervous system."

As demonstrated by Lou et al. (1999) different meditation techniques activate various brain structures, depending on the nature of technique itself. Hence, during the task of body-weight feeling Lou's meditators showed increased activity in superior frontal gyrus, which is related to self-awareness (Goldberger, Harel, & Malach, 2006), visualization activated occipital regions that are dedicated to visual processing, and during the task of abstract feelings of joy there was shown activation in the left frontal region which is according to the valence theory responsible for positive emotion processing (Hellige, 1993).

Frontal cortex was previously recognized the key neurological correlate to meditation, and especially its prefrontal structures seem to be essential during all the meditation session. Prefrontal cortex has great number of connection to both higher and lower brain structures, in meditation the basic ones are interconnections with reticular activating system (RAS) which is believed to be centre of arousal and motivation, and limbic system that is responsible especially for emotions and memory.

Esch (2004) noted that deep CNS structures are crucial components of the neural RR pathway and that these components primarily consist of limbic structures. Among the most important increases in rCBF following or coming along with meditation he names the dorsolateral prefrontal cortex, inferior or orbital frontal cortices/anterior regions, inferior parietal lobes, precentral and postcentral gyri, temporal lobes, cingulate gyrus, hippocampus and parahippocampus, amygdala, globus pallidus/striatum, thalamus, and the cerebellar vermis. There are some inconsistent results with regard to the parietal cortices, some studies showing simultaneous activation along with prefrontal areas, yet other studies demonstrating an inverse correlation between the DLPFC and the ipsilateral superior parietal lobe (A. Newberg et al., 2001; A. Newberg et al., 2003).

To describe the possible pathways of meditation, and decide what part all the above mentioned structures play in its neural network, is beyond the extent of this work. However, based on the evidence coming from the neuroimaging studies there can be drawn some general conclusions regarding the neural correlates of meditation:

1. neural activity is highly dependent on the character of meditation technique used
2. frontal cortex plays crucial role during the whole meditative session
3. meditation activates emotional, attentional and motivational neural circuits, as well as frontoparietal structures and circuits related to memory

2.6. Neurochemical perspective

Founded on previous rudimentary neuropsychological model explaining the brain mechanisms underlying meditative experiences (d'Aquili & Newberg, 1993) and including new findings of neural and chemical nature of meditation and religious practices, Newberg and Iversen (2003) propounded a model of neurophysiological network possibly associated with meditative states (Image II.). Further we will discuss this model and possible implications it has on meditation.

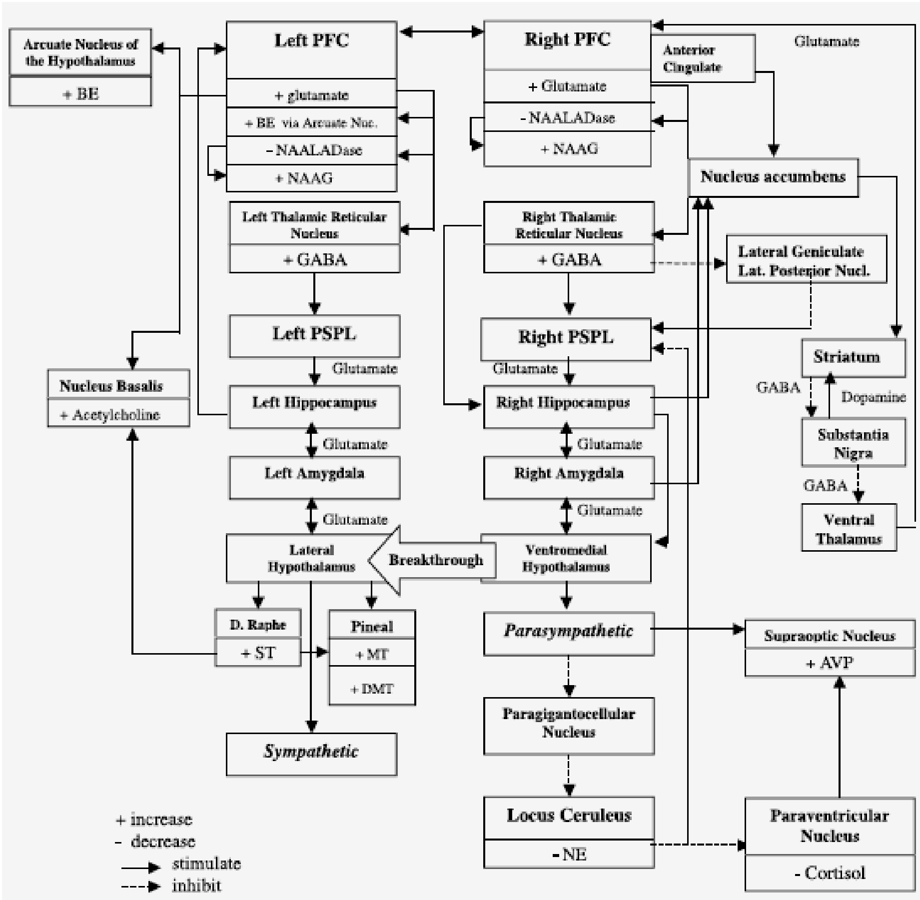

Image II. Neurochemical model (from Newberg & Iversen, 2003).

2.6.1. Prefrontal and Cingulate Cortex

Several studies have demonstrated that wilful acts and tasks that require sustained attention are initiated via activity in PFC, particularly in the right hemisphere (Frith et al., 1991; Ingvar, 1994). Significant unilateral left dorsolateral prefrontal activation during semantic tasks suggests that the left inferior prefrontal cortex is the anatomical region involved in 'working with meaning', and that the activation does not reflect willed action (Kapur et al., 1994). DLPFC was confirmed to be critical to executive-attention functions in actively maintaining access to stimulus representations and goals in interference-rich context (Kane & Engle, 2002). Willed actions are controlled by a network of frontal cortical (DLPFC, supplementary motor area, anterior cingulate) and subcortical (thalamus and basal ganglia) areas (Jahanshahi & Frith, 1998).

The anterior cingulate cortex (ACC) can be divided anatomically based on attributed functions into executive (anterior), evaluative (posterior), cognitive (dorsal), and emotional (ventral) components (Bush, Luu, & Posner, 2000). It was suggested that ACC takes part in emotional awareness (Lane et al., 1998). ACC is connected with the PFC and parietal cortex as well as the motor system and frontal eyes fields, and is involved in executive attention and metacognitive regulation (Posner & DiGirolamo, 1998). The cingulate gyrus appears to take part in focusing attention, apparently in conjunction with the PFC, anterior parts being executive and posterior evaluative (Vogt, Finch, & Olson, 1992). In one later study it was suggested that cingulate, and especially ACC, actually coordinates and integrates activity of multiple attentional regions throughout cerebrum (Peterson et al., 1999). One recent study of neural correlates of attention revealed that long-term practitioners had significantly more consistent and sustained activation in DLPFC and ACC during meditation than had the group of short-term practitioners, and that this activation may vary over the time of a meditation session (Baron Short et al., 2007).

Since meditation requires an intense focus of attention, it is logical that Newberg's meditation model begin with activation of the PFC, particularly in the right hemisphere, together with cingulate cortex. This conception is supported by the increased activity in these regions typical for the onset of meditation and observed in several EEG and brain imaging studies of volitional types of meditation (Wallace, 1970; Banquet, 1973; Herzog et al., 1990-1991; Lazar et al., 2000; A. Newberg et al., 2001). Quantitative analysis demonstrated increased activity in the PFC bilaterally, but greater on the right (Austin, 1988/1999; A. Newberg et al., 2001, Img. I.). Therefore, meditation seems to begin by intention and will to clear one's mind of thoughts or focus on an object, and thus by activation of prefrontal and cingulate cortex.

The prefrontal and cingulate cortex activation seems to be mediated by the excitatory neurotransmitter glutamate (Ingvar, 1994). Dopamine (DA) hypofunction was related to glutamate-stimulated release defect and on rat model it was demonstrated to play role in attention deficit hyperactivity disorder (Russell, 2003). Also there is an evidence which indicate that obsessive compulsive disorder is a hyperglutamatergic and ADHD hypoglutamatergic condition, with prefrontal brain regions being especially affected (Carlsson, 2001).

2.6.2. Thalamus as Part of an Attentional Network

Based on several animal studies showing that activated PFC innervates the reticular nucleus of thalamus (TRN) by excitatory neurotransmitter glutamate (Glu), Newberg's model propose that this thalamic activation further influences sensory processing, the lateral geniculate nucleus of thalamus being responsible for visual data routing to the striate cortex. In the model the lateral posterior nucleus of thalamus provides the posterior superior parietal lobule (PSPL) with the sensory information it needs to determine the body's spatial orientation. When excited, TRN secrets the inhibitory neurotransmitter γ-aminobutyric acid (GABA) onto the lateral posterior and geniculate nuclei, cutting off input to the PSPL and visual centers in proportion to the reticular activation.

The activation on thalamus is far more complex than Newberg and Iversen propose. It was suggested that in humans the pulvinar and the mediodorsal nuclei of the thalamus represent the targets of a prefrontal top-down (voluntary) modulation of attention (LaBerge & Bauchsbaum, 1990), and it is speculated that in fact several ventro-lateral thalamic nuclei are involved in the interaction between arousal and attention, TRN being one of them (Portas et al., 1998). However, this hypothesis hasn't been supported by any serious data and remains only a speculation. TRN has many connections and receives axonal collaterals from the corticothalamic, thalamocortical, and midbrain reticular formation projection systems; nevertheless, evidence on details of reticular connections is incomplete and there is clear need of "much more detailed information about these highly organized connections before we can understand exactly how the thalamic reticular nucleus might be influencing thalamocortical pathways in attentional mechanisms or in other, as yet undefined, roles" (Guillery, Feig, & Lozsádi, 1998, p. 28). On an animal model it was shown that activation of the TRN visual center is in the awake, attentive animal, predominantly under visual cortex control (Montero, 1999, 2000). Variety of pharmacological, electrophysiological, and biochemical evidence supports a role for Glu as a transmitter in thalamocortical fibers to primary sensory areas (Kharazia & Weinberg, 1994). It has been demonstrated that the activation of corticothalamic fibers influences functioning of thalamocortical relay, suggesting that shifting from drowsiness to arousal may be a consequence of increased activity in the circuit itself, in addition to effects of modulatory transmitters released from neurons located in lower lying brain structures, and that the existence of such intrinsic and descending activating mechanisms in thalamocortical systems may actually explain the ability to consciously modulate ones own level of arousal (McCormic & von Krosigk, 1992). It was suggested that the mechanism by which the thalamocortical network transform from one form of activity to another is due to differential activation of thalamic $GABA_{A,B}$ receptors in response to varying corticothalamic input patterns (Blumenfeld & McCormic, 2000).

Attentional activation of thalamus was documented by a number of studies, the mechanism, however, remains unclear. There is evidence that support the role of Glu in such process, yet there are indications that dopaminergic system participate in regulation of glutamatergic system. Experimental data show significant alternation in attentional processes, thus raising the question of direct involvement of DA in regulating attention (Nieoullon, 2002). However, propound meditation model doesn't reflect these findings at all. For sure it can be stated that activation of thalamus triggers inhibitory GABA secretion that regulates the main output neurons of the thalamus, the thalamocortical relay cells; predominantly the $GABA_{B(1a,2)}$ receptor subtype controls the release of Glu from corticothalamic fibers, TRN as an origin of this corticofugal inhibition being in turn excited by either thalamic or cortical inputs (Ulrich, Besseyrias, & Bettler, 2007). For the presented complex nature of thalamic functioning we can conclude, that at this level is Newberg and Iversen's model founded rather on speculations and that it neglects some serious data about thalamic neurochemical interconnections.

2.6.3. Posterior Superior Parietal Lobule Inhibition

As mentioned above, at another level of the model the TRN secrets neurotransmitter GABA onto the lateral posterior and geniculate nuclei, cutting off input to the PSPL which is heavily involved in the analysis and integration of higher-order visual, auditory and somaesthetic information, and is involved in attentional tasks related to spatial orientation. According to Newberg and Iversen "deafferentation of these orienting areas of the brain is an important concept in the physiology of meditation [because] they alter the perception of the self" (2003, p. 286).

Indeed, deafferentation of the PSPL has been supported by two imaging studies demonstrating decreased activity in this region during intense meditation (Herzog et al., 1990-1991; A. Newberg et al., 2001). Nevertheless, other imaging studies do not duplicate these findings and show either insignificant change in parietal regions, or increased activity. EEG studies demonstrate rather significant increases in parietal activity. According to Esch et al. (2004) the reported findings with regard to the parietal cortices are 'inconsistent'. Dunn et al. (1999) reported grater parietal EEG activity during concentrative form than mindfulness, however, there was also suggested frontoparietal activation produced by mindfulness meditation (Lutz et al., 2004). It is probable that different meditation techniques may cause parietal activation/inhibition. Posner and Petersen (1990) proposed that SPL activation is related to imagery. Even though there is no evidence supporting this suggestion, it is still surprising that Newberg & Iversen incorporated PSPL inhibition in their general model of meditation, when there is clear evidence that it isn't universal feature of meditation.

2.6.4. Limbic Activation

The hippocampus has been documented to play role in arousal and was suggested to modulate and moderate cortical arousal by increases and decreases of its own activity; it was propounded that during high neocortex stimulation, hippocampus functions at much lower level and monitors reception and processing of information, while low neocortex arousal it compensates by increasing its own level of arousal (Joseph, 1990).

In anatomical terms, the hippocampal archicortex can be conceived as an 'appendage' of the large neocortex, the main function of of the hippocampal formation being modification of its inputs by feeding back a processed 'reafferent copy' to the neocortex (Buzsáki, 1996). According to Acquas, Wilson, & Fibiger (1996), there is satisfactory evidence that basal forebrain cholinergic neurons with projections to the frontal cortex and hippocampus are activated by behaviourally salient stimuli, suggesting that these neurons are involved in arousal and/or attentional processes; lesions in these basal forebrain neurons have been reported to result in impairments in memory and attention, and have been associated with Alzheimer's disease, which is characteristic by deficits in cognition and attention. Even though the acetylcholine (ACh) associated aspects of attention are related to detection, selection and processing of stimuli and associations (Sarter & Bruno, 2000), which are not primarily involved in the state of awareness as evoked by meditation, the role of ACh in arousal cannot be simply ruled out, as presented in Newberg and Iversen's model.

Hippocampus is activated by glutamate metabotropic receptors in hippocampal CA3 pyramidal cells and it was found that Glu can induce either a fast or slow excitation (Charpak et al., 1990; Charpak & Gähwiler, 1991). The same two basic modes of operation (i.e., steady firing and burst discharge) display also principal neurons in neocortex and thalamus (McCormic & von Krosigk, 1992). Glu really seem to be the main neurotransmitter in the attentional processes connected to meditation, including hippocampal activation. Nevertheless, as the dichotomy of presented hippocampal operation is regulated by hippocampopetal subcortical modulatory system, there is arising a question of neuronal connectivity between the hippocampus and cortex (Buzsáki, 1996). The proposed descending pathway seems to be influenced at least to some level by other structures which role is, however, ignored. Apart from above mentioned basal forebrain, there arises a question of involvement of basal ganglia in meditation-enhanced neurophysiological changes. Some imaging studies showed significant basal ganglia activation during meditation session (Austin, 1988/1999; Ritskes et al., 2003). Basal ganglia were associated with attention focusing and willed actions (Brown & Marsden, 1998; Jahanshahi & Frith, 1998), and their role in attentional network, therefore, shouldn't be ignored.

Hippocampus functioning is closely related to the amygdala which is responsible mainly for emotion processing. Joseph (1990) suggested that the hippocampus greatly influences the amygdala, such that they complement and interact in the generation of attention, emotion, and certain types of imagery. Newberg and Iversen included this suggestion in their model, despite of lack of empirical evidence. Indeed, during a cognitive evaluation of angry and fearful facial expressions there has been documented increased activity in right prefrontal and anterior cingulate cortex, as well as orbitofrontal cortex, which positively correlated with amygdalar activation (Hariri, Bookheimer, & Mazziotta, 2000; Hariri et al., 2003; Ochsner & Gross, 2005). These observations, however, do not elucidate the mechanism of neural circuity engaged in emotional and attentive processing. The hippocampal stimulation of amygdala remains only a hypothesis with no empirical evidence. In fact, some recent findings propose that the amygdala actually stimulates hippocampus. The amygdala has reciprocal connections with sensory cortical processing regions, such as the visual cortex (Amaral, Behniea, & Kelly, 2003), which allows respond to an emotional stimulus rapidly, even before awareness and cortical processing (Whalen et al., 1998; O'Connor et al., 2002), and irrespective of attentional focus (Vuilleumier & Schwartz, 2001; A. K. Anderson et al., 2003). These results support proposed two parallel pathways to amygdala, one subcortically mediated, thalamo-amygdala pathway, and one cortically mediated, thalamo-cortico-amgdala pathway (LeDoux, 1996; A. K. Anderson et al., 2003). It seems that amygdala activity is triggered rather by cortex or thalamus than hippocampus, which function in contrary seem to be at least to some extent amygdala-mediated. It was also suggested that the limbic system consist of two divisions, a paleocortical division (amygdala, dorsomedial thalamic nuclei, and the orbitofrontal, insular, and temporal polar cortices, with extensive connections to dorsolateral prefrontal cortex and posterior parietal association cortex) which is responsible for processing of information concerning the external world, and the archicortical division (hypothalamus, anterior thalamic nuclei, cingulate gyrus, hippocampus, with connections to brainstem reticular formation) which mediates important aspects of learning, memory, and attentional control, as well as information related to internal states (Mega et al., 1997). The propound model of Newberg and Iversen therefore seem to be erroneous in the idea of descending hippocampal connections to amygdala in attentional processing.

2.6.5. Hypothalamus and Autonomic Nervous System Changes

Newberg and Iversen propose that the right amygdala stimulation results in activation of the ventromedial portion of the hypothalamus and a subsequent stimulation of the peripheral parasympathetic system. Parasympathetic changes can be associated with initial relaxation and later state of quiescence. The heart rate and breathing moderation would lead to reduced innervations of the pons' locus coeruelus (LC) by paragigantocellular nucleus of the medula. Decreased LC stimulation is connected to norepinephrine (NE) decreases. Reduced LC activity would also lead to reduced supplementation of the PSPL and the lateral posterior nucleus with NE, a neuromodulator that increases susceptibility of brain regions to sensory input. Therefore, NE would decrease the impact of sensory stimulation to PSPL, contributing to its deafferentation.

Newberg and Iversen also suggest that the LC would deliver less NE to the hypothalamic paraventricular nucleus, which typically secrets corticotropin-releasing hormone (CRH) in response to NE innervation. Less CRH would cause lower adrenocorticotropic hormone (ACTH) secretion and would lead to lesser production of cortisol by adrenal cortex. Cortisol is known to be one of the body's stress hormones and its lower secretion would therefore help maintain the state of calm awareness during meditation.

Indeed, it has been documented that the amygdala is extensively interconnected with hypothalamus; however, the role of amygdala is almost exclusively related to fear processing and therefore has rather excitatory effect (Davis, 1992). Newberg and Iversen misinterpret Davis' data concerning the hypothalamus functioning when they propose that ventromedial thalamus leads to peripheral parasympathetic activation. Davis connects amygdaloid projections rather to excitatory states and vigilance (Davis, 1992; Davis & Whalen, 2001). In fact, proposed amygdala stimulated hypothalamic structures are involved in activation of the sympathetic nervous system as seen during fear and anxiety (LeDoux et al., 1988). On animal model it has been documented that ventromedial hypothalamic lesions lead to PSNS hyperactivity and SNS hypoactivity (Inoue et al., 1995; Jeanrenaud, 1995). Hence, the idea that ventromedial hypothalamus stimulates PSNS is incorrect. Davis (1992) proposes that the role of amygdala in attentional processes is stimulatory and that amygdaloid projections to ventral tegmental area (VTA) may mediate state-induced increases in dopamine metabolites in the prefrontal cortex.

Hypothalamus may really evoke parasympathetic changes, but the pathway described by Newberg and Iversen doesn't seem to be accurate. It was found that lateral and ventromedial hypothalamus controls sympathetic and parasympathetic inputs into liver, and therefore regulates secretion of cortisol (Shimazu, 1981), and that paraventricular nucleus of the hypothalamus may elicit increases/decreases in blood pressure via excitatory connections with reticulo-spinal vasomotor neurons (Yang & Coote, 1998).

In this depths of the brain the propound model of Newberg and Iversen seems to be built on speculation and misinterpretation of current knowledge. The density of interconnections of subcortical limbic structures makes it hard to conclude what is their role in attentional processes and how they add to the course of meditation.

2.6.6. Conclusions Coming from the Model

Newberg and Iversen's model can be without hesitation labelled 'not scientific'. Not only it disregards data that are contradictory to the proposed neurochemical circuitry but it also misinterprets some commonly known facts and cites authors whose conceptions and hypotheses were never confirmed.

The most obvious blunder is, however, the level of generalization Newberg and Iversen use. Their model is built on a peculiar mix two well distinguished forms of meditation, concentrative and mindfulness. These two forms have been well differentiated from relaxation in EEG studies (Dunn et al., 1999) and are recognized as two unique kinds with specific attentional patterns that most probably rouse different attentional circuitry. Even though there is still little knowledge about how the two techniques function in respect to attention, it is obvious that they shouldn't be mingled into one layout. It is apparent that mantra meditation will activate different brain regions than mindfulness or visualization. And that even very similar techniques may evoke different brain structures. General model of meditation therefore seem to be highly inappropriate notion.

Nevertheless, the proposed model can be useful because it arises many questions regarding how meditation really works. Some of the proposed ideas are likely to stimulate further research on meditation and attentional processes, and also to orient future investigation on neurochemistry of meditation.

It is impossible to draw whatever conclusion from a model that has so many obvious flaws. With respect to neurochemical functioning of meditation it doesn't give us clear idea how meditation may affect brain chemistry. In fact, the basic questions concerning the role of dopamine, serotonin and melatonin in chemistry of meditation remain unanswered and the model doesn’t even aim these substances. The current research on neurochemistry of meditation is mostly related to stress coping and is still at its beginning. Hence, it will take some time to extend the knowledge on meditation and provide information that could elucidate how it really works.

Neurofeedback

3.1. Definition

"Neurofeedback is the use of electroencephalograph (EEG) biofeedback to modify cortical (brain) activity, alter states of consciousness, and affect cortically mediated physical and psychological functioning. Neurotherapy is the clinical application of neurofeedback to modify cortical functioning in clinically beneficial ways." (La Vaque, 2002, p. 123)

Neurofeedback (NFB), also called neurobiofeedback or EEG biofeedback is a technique that presents the user with real-time feedback on brainwave activity, typically in the form of video display but can use also auditory or tactile modality. The aim is to provide real-time information to the CNS as to its current activity. The basic principle of the whole biofeedback concept stands on the idea of operant conditioning. Kropotov (2008) states that neurofeedback is based on two facts:

1. the brain state (including any dysfunction or dysregulation) is objectively reflected in parameters of EEG recorded from the scalp
2. the human brain has plasticity to memorize the desired (and thereby, rewarded) state of the brain.

In the NFB practice are some current parameters of EEG recorded from a subject's scalp (normally EEG power in a given frequency band, or different EEG bands power ratio) presented to the subject through above mentioned outputs with the task to voluntarily alter these parameters to more efficient mode of brain functioning. Prior to neurotherapy the subject's EEG is compared to normalized data and the aim of subsequent NFB training is to adjust a pathologically abnormal EEG pattern to this normalized criterion.

Most recently has been the idea of technical feedback to CNS adapted also to more modern technology. Now there exist studies that are exploring the brain-computer interface technique using fMRI as a way to monitor and actively modulate one's brain activity and that suggest methods that may offer potential utility for fMRI-based neurofeedback (Yoo & Jolesz, 2002; Weiskopf et al., 2004; Yoo et al., 2004). There have also been attempts to interconnect NFB with virtual reality as to create environment more appropriate for attention enhancement (Cho et al., 2004; Mingyu et al., 2005).

3.2. History of Neurofeedback

The history of NFB is closely related to the clinical use of electroencephalography. One of the major proponents of electrophysiologically based physiology of the nervous system had been Emil Du Bois-Reymond, who coined the term 'negative variation' for a phenomenon occurring during muscle concentration when galvanometer indicated an unexpected decrease in current intensity; the term was later resurrected in the earliest EEG research (Niedermayer, 2005).

Probably the first scientist to record spontaneous electrical activity of the brain was Richard Caton. In July 1875 he presented his findings before the British Medical Association in Edinburgh and summarized it in a written article published later that year. Caton mentioned the possibility to influence the currents of certain brain areas in rabbits and monkeys by impressions through the senses, which was apparently the first evoked potentials record (Finger, 1994). The importance of Caton's discovery had recognized and acknowledged Hans Berger who cited him in his 1929 report on the discovery of alpha waves. Berger was first to record EEG from human subjects and is reckoned the father of electroencephalography (Finger, 1994). After Berger's description of different EEG rhythms the popularity of new technology grew rapidly and in 1930s and 1940s electroencephalography became the object of much interest in the realm of psychiatry and psychophysiology until it developed into standard diagnostic and clinical technique after 1945. Finally, with the development of digital computer technology in 1960s and 1970s it became feasible to assess and quantify precisely many more EEG parameters than before. This development practically meant the beginning of QEEG (Cantor, 1999).

The Second important scientific line leading to development of NFB technique was the physiology of conditioned reflexes. Classical Pavlovian conditioning and the methods developed by behaviourists in the USA form the root of this source. In 1930 the founder of cybernetics Norbert Wiener[19] in collaboration with a Mexican psychologist Arturo Rosenblueth introduced concept of feedback in relation to biological system (Kropotov, 2008). Five years later, in 1935, Russian physiologist Petr Anokhin incorporated this biological feedback in his theory of functional systems as a 'backward afferentation' flowing through different sensory channels to CNS after each action, and as such he put forward an alternative to the predominant concept of reflexes which linear information was unbearable in a long-term perspective (Red'ko, Prokhorov, & Burtsev, 2004). The key element of the theory was neuronal feedback – an interaction between 'acceptor' (an anticipatory neural template of a required result placed into memory before each adaptive action) and behavioural adjustment of the animal.

The real origin of neurofeedback dates back to 1960s when two American researchers, Joe Kamiya and Barry Sterman, independently began to explore the phenomena associated with brainwaves. Both experimenters found that positive conditioning of certain rhythms could lead to an increase of such rhythms in overall EEG record. Concretely, Sterman and his

[19] **Norbert Wiener** founded cybernetics shortly after the WW II. Cybernetics is often defined as the interdisciplinary study of the structure of regulatory systems. Wiener's area of interest was brain-machine interconnection. During his work at MIT he was personally responsible for recruiting prominent scientists and forming a research team in cognitive science, neuropsychology and the mathematics and biophysics of the nervous system. These people later went on to make pioneering contributions to computer science and artificial intelligence (wikipedia.org).

colleagues observed that sensorimotor rhythm[20] in cats was associated with state of relaxation. When they tried to determine whether the occurrence of this EEG pattern could be enhanced by reward they found that the production of activity really increased. Joe Kamiya was studying consciousness by attempting to elicit alpha wave activity in the brain. He found that some individuals could learn to identify and increase production of alpha in their brain. Using simple reward system, and with his subjects' cooperation, he conducted the first NFB training (Robbins, 2001).

In 1972 Sterman published his findings about efficiency of neurotherapy in the treatment of epilepsy. The results had drawn attention of Joel Lubar who became interested in Sterman's work and replicated the results of his study. Later he oriented his interest on the use of neurofeedback in hyperactivity and attention issues (Demons, 2005). From publishing his first study on the topic in 1976 he conducted number of studies on the efficacy of NFB treatment of ADD/ADHD. In one of his later papers Lubar noted that he observed significant improvement after NFB treatment in about 90% of his 250 patients (Lubar, 1991). Sterman, Lubar, and Margaret Ayers who opened the first commercial neurofeedback clinic, have oriented their efforts on cognitive rehabilitation and mental disorders, and determined the direction of NFB application (Demons, 2005). Participants in the early studies of Sterman and Kamiya also reported increased feelings of inner calmness and variants of these alpha protocols are now used for stress management training.

3.3. Application

Similarly to meditation, neurofeedback has become a widespread phenomenon which draws attention of public, as well as the scientists. There are a number of studies on the efficiency of neurofeedback in various disorders and psychopathologies. Sieghfried Othmer (2003) summarizes that NFB application in areas such as:

- ADD/ADHD
- Anxiety-depression spectrum
- Seizures and addictions
- Disruptive behaviour disorders (such as Oppositional-Defiant Disorder and Conduct Disorder)
- Autism Spectrum and Asperger's Syndrome
- Bipolar Disorder
- Specific learning disabilities (including Dyslexia)
- Sleep disorders

[20] **SMR**, μ rhythm, or arciform rhythm is oscillatory rhythm of synchronized electromagnetic brain activity of somatosensory cortices at rest, usually encompassed in the alpha range (8-13Hz). The amplitude is stronger when the sensory-motor areas are idle and it decreases with their activation. Neurofeedback is believed to increase SMR and benefit people with epilepsy, autism, ADHD and learning disabilities. However, the nature and meaning of SMR remains unclear.

- Traumatic brain injury and stroke
- Post-Traumatic Stress Disorder
- Women's issues such as PMS and menopause
- Issues of aging such as Parkinsonism and dementia, and Age-Related Cognitive Decline
- Pain syndromes such as migraine, as well as the management of chronic pain

In his overview Othmer differentiates among three groups of conditions the NFB training can be applied to:

1. Conditions caused by dysregulation (impairment of a physiological regulatory mechanism), such as attention deficit disorder and PMS. In these cases "self-regulation strategy should constitute a comprehensive remedy. Moreover, once re-regulation has been achieved, by whatever means, the defining aspects of the condition will no longer meet criteria to sustain a diagnosis."
2. Conditions where dysregulation merely accompanies a more structural deficit, such as autism, traumatic brain injury, or foetal alcohol syndrome. In these instances is the possible progress constrained by organicity, nevertheless, the attempt at remediation seems, according to Othmer, to be quite generally worthwhile.
3. Degenerative conditions such as Parkinsonism and the dementias, where "the EEG training may succeed in restoring and then maintaining function even in the face of continuing organic deterioration. In such cases, the training has to be kept up over time in order to maintain levels of function."

It is evident that supporters of both, meditation and neurofeedback claim positive results of their application on various conditions. Both techniques are applied in similar manner and the range of their relevance is practically identical. There is a difference though as to the perseverance of obtained results. While research demonstrated that the effect of meditation on NS is limited and disappears without continued practice (Patel, 1977), the neurofeedback supporters claim that changes gained by NFB training in the same range of conditions are irreversible and that there is an ongoing remission of symptoms after discontinuation of NFB treatment (Abarbanel, 1995). This is striking difference if one takes into account the fact that neurofeedback is practically only technological upgrade of meditative technique and that it works with the same principles. The parallel meditation-neurofeedback is mentioned in every serious publication about neurofeedback and the authors admit that self-regulation activity as we know it from neurofeedback actually descends from meditative traditions, especially those connected to yoga and martial arts (Swingle, 2008). Therefore it would be surprising if the cumulative effects of meditation and NFB led to different results.

3.4. Controversy over Methodology

Ever since its introduction, neurotherapy has raised strong emotions and controversies concerning its effects and application. For three decades there has been a scientific dispute about legitimacy of the method and its efficacy in the treatment of various conditions. On one side stand those who propagate neurofeedback, on the other those whose research is often funded by medical corporations. The most noticeable is probably the controversy over ADD/ADHD treatment. It is hard to draw any conclusion and it is very improbable that the hassle will be resolved in next few years.

In the United States is neurofeedback acknowledged adequate treatment method and is reimbursed for only by some insurance companies, while most do not cover the costs of NFB training. However, most professionals have chosen not to accept insurance on neurofeedback and are reporting significant success anyway. The clients who are looking for an alternative to medication are often willing to pay for NFB training versus other forms of therapy. Training can be really expensive though, taking into account price of one session and the number of sessions which patient has to undertake (minimum 20, normally 40 and over). Neurofeedback practitioners therefore like to emphasize that NFB training is alternative to currently recognized therapeutic methods and that “it is likely to remain classified for some time as part of Complementary or Alternative Medicine” (Othmer, 2003). Indeed, neurofeedback can be considered alternative to classic ADD/ADHD treating methods as NCCAM affiliates biofeedback methods to complementary and alternative medicine, more specifically to mind-body medicine.

Probably the most problematic application of neurofeedback, also raises the most questions and objections from some research experts is ADHD treatment. As mentioned above, Othmer (2003) classifies this condition a dysregulation, and thus of functional origin. However, this view is rather daring when we consider that the exact causes of ADHD still remain unclear and that the organic origin not only has not been ruled out, but the accumulating evidence and recent findings make the hypothesis of organicity of ADHD on the contrary highly influential (Mulas et al., 2007). As the terms functional/organic are being slowly replaced, the most common classification says that ADHD is a neurodevelopmental disorder, as well as autism, autism spectrum disorders, and a number of other conditions (Gregg, 2009). Very often are cited “the high rates of comorbidity between ADHD and other psychiatric and neurodevelopmental disorders [which] raise several important issues for understanding the neuropsychology of ADHD” (Tannock, 2002, p. 772) Hence, ADHD seems to fall into the second category which Othmer (2003) classifies “conditions where dysregulation merely accompanies a more structural deficit [and] in these instances is the possible progress constrained by organicity, nevertheless, the attempt at remediation seems to be quite generally worthwhile.” If that all is true, the only logical question is - how Othmer can claim (based on the example of ADHD) that “once re-regulation has been achieved, by whatever means, the defining aspects of the condition will no longer meet criteria to sustain a diagnosis"? The proclaimed permanence of results achieved by NFB training remains at least suspicious and is not backed by serious research.

Although there are a number of published studies on neurofeedback treatment of ADHD in which positive results have been reported, the design and implementation of these studies bear significant limitations which make many leading ADHD researchers consider NFB promising, but unproven technique (Rabiner, 2008). Based on the five-level grading guideline for the evaluation of the efficacy of treatments published by the Association for Applied Psychophysiology and Biofeedback (La Vaque et al., 2002), Monastra concludes that NFB is probably efficacious (level 3) for ADHD (2005). However, some authors are more fundamental and claim that many studies published on NFB efficiency "have suffered from significant methodological weaknesses that make interpretation of the results and conclusions about the actual effect of EEG biofeedback impossible" (Loo & Barkley, 2005, p. 69). Some of the flaws of studies on NFB as a treatment for ADHD had been identified before, but according to Loo & Barkley who reviewed some recent studies "the same problems with scientific methodology that existed then [decade ago] continue to exist with these newer studies" (2005, p. 69):

- Lack of control groups
- Confounding of several treatments within NFB group (e.g. medication)
- Small sample sizes
- Diagnostic uncertainty about the children in the study
- Lack of placebo control procedures
- Absence of 'blinding' of the evaluators
- Lack of randomization
- Lack of rigorous peer review

The methodological issues of studies supporting NFB application have been questioned also in some other recent reviews, the most prominent being those of Lohr, Meunier, Parker, and Kline (2001), Waschbusch and Hill (2001), and Kline, Brann, and Loney (2002). These papers in answer to previously published study of Rossiter and La Vaque (1995) criticised methodological flaws such as (1) using an active treatment control rather than a waiting list or other nontreatment control, (2) the nonrandom assignment of patients to treatment and control groups, (3) providing collateral treatments to patients in each group, (4) using assessment instruments that were not standardized, lacked ecological validity, could not discriminate between ADHD and other psychiatric disorders, and were not sensitive to treatment effects, (5) providing EEG feedback contaminated by ocular artifact, and (6) conducting multiple non-alpha protected t tests. In his reply to this critique Rossiter (2004) acknowledged wrong choice of statistical methods as stressed in the last point; however, he refused the other criticisms claiming that they were not valid or not supported by research literature, that they were based on unsupported opinions of the critics, relied on redefining the study as efficacy rather than effectiveness, and that they reflected lack of familiarity with the relevant research literature, NFB equipment, and ADHD treatment protocols. Some of the Rossier's comments are very curious though and rise further doubts. In fact, in reply to his critics he simply avoids direct confrontation with the facts presented and tries to debilitate their relevancy (e.g. his undermining of random assignment in evaluating effectiveness), as well as competence of their authors.

One of the major problems of NFB is that, similarly to meditation, it's not really clear what neural responses it rouses. In the last two decades there has been growing interest in both methods and hundreds of reports on their effects and efficiency in dealing with various conditions were published. One of the problems meditation research faces is the diversity of techniques and variation of results. There are usually two research designs when studying meditation, direct imaging and efficacy/effectivity research. Especially direct imaging of neural correlates of meditation raised lot of questions about how meditation really functions and has recently oriented the research on subcortical pathways associated with attentional processes, such as limbic structures. However, neurofeedback research must be designed in whole other way as EEG recording make it impossible to image real-time brain activity during therapy itself. Of course it allows recording EEG during the NFB session and thanks to more advanced devices QEEG analysis is also possible; nevertheless, the role of deeper neural pathways of attentional processes remains uncertain and it can be estimated only on indirect data and on subcortical QEEG which has still its limitations. New emerging technologies based on fMRI therefore bear lot of expectations and are believed to elucidate deeper mechanisms underlying NFB training.

3.5. How Does it Work?

As said above, the principal mechanism of NFB is based on the idea of operant conditioning. Brain waves rise and fall in rhythmic and arrhythmic patterns. Neurofeedback is designed to reinforce the desired wave pattern in real-time conditions. If the wanted pattern occurs, immediate feedback in the form of positive reinforcement is given. Brain plasticity allows regular training to progressionally normalize patient's EEG power spectrum. Nonetheless, do these EEG changes automatically mean that patient's symptoms have also normalized? Neurofeedback opposers claim it's not possible, the proponents defend such believe. To make any conclusion it is necessary to understand how neurofeedback functions.

While modern neuroscience is fundamentally oriented on neurotransmitters, treating various conditions chemically, neurofeedback is founded on totally different paradigm, intervening in the realm of frequency. Based on activation theory of arousal continuum, there is a speculation that arousal levels may be the major component in a whole host of disorders.

Arousal is suggested to form a framework for attention-demanding, and hence, for many cognitive tasks. Over or underarousal may be compared to processor operating speed. Processor, the brain, is designed to work at some frequency range and if the frequency is lower or higher, it alters brain functionality. Neurofeedback aims to change the frequency in different neural circuits and thus change their function. The main component of these changes is formed by adjustment of neural circuity related to arousal. Alterations in frequency towards normal spectrum should therefore produce subsequent (or related) modification in chemical processes. The proponents of NFB claim that training in some neurofeedback-based technologies, such as audio-visual entrainment (AVE), can stimulate changes leading to function alterations in subcortical structures like the limbic system, and may even modify brain chemistry and structures. Siever (2006) names in particular neurotransmitter changes, dendritic growth, cerebral blood flow, metabolism and limbic stabilization.

Probably the most recognised model of NFB functionality was proposed by Siegfried and Susan Othmer. The fundamentals are based on actuation of cortical frequency range which, through thalamocortical networks, affects brainstem mechanisms “in a manner that enables the latter to then help restore timing integrity within all neural networks” (Evans & Rubi, 2006, p. 73). NFB is therefore hypothesised to disturb brain timing due to its operant conditioning mechanisms and elicit a brain response, which over time lead to revitalized normal rhythmicity, phase relationship, and timing integrity among neuronal assemblies, producing more efficient information transfer and regulatory functioning.

3.6. Training Protocol

Prior to any NFB treatment it is necessary to evaluate brain activity as to its frequency components. Any NFB training should follow thorough QEEG examination, though there are quite constant consequent procedures, to ensure correct application adjusted to individual needs.

At the moment the most commonly used NFB training protocols are designed to inhibit or increase EEG amplitude (power) within a frequency band or combination of bands (Evans & Rubi, 2006). Probably the most applied protocols are related to above mentioned over and underarousal symptoms. Underarousal is expressed by increased amplitude in some lower frequency band and decreased amplitude in higher frequency bands, which are related to attentive and cognitive processes. Most generally are implemented trainings that target lower frequency amplitude inhibition and simultaneous increase in higher frequency. Beta-1 and beta-2 bands have been over the years demonstrated to accompany most attention-related tasks and to be closely connected to cognitive performance dependent on arousal level. Irregularities are usually found in central and/or frontal areas and typically are linked to inhibited state of sensorimotor system (Egner & Sterman , 2006).

In a recent study, two training protocols were investigated in relation to specific cognitive tasks. Vernon et al. (2003) explored the possibility to enhance cognitive performance by increasing SMR and theta activity. Theta activity had been suggested to play role in working memory (Grunwald et al., 2001), whereas SMR activity had been studied quite thoroughly over the years for its association with attentive tasks (Egner & Sterman, 2006). The results of the study suggest that short NFB training could lead to cognitive enhancement in tasks dependent on SMR frequency. Surprisingly, SMR enhancement resulted in better performance in working memory tasks and only some alteration in attention performance. However, theta activity showed no increasement following the NFB training.

This study, disregarding the significance of the results, shows how important it is to settle right training protocol, but also demonstrates the complexity of neural structures and their involvement in different processes. After fifty years of neurofeedback practice and one hundred years of electroencephalography, very little is known about human brain bioelectric activity and about the functions that different frequency bands underlie. NFB protocols can be therefore criticized for the fact, that they are almost ultimately built on SMR assumption and lack extensive theoretical background which would support their application.

Electroencephalography

The interpersonal and intrapersonal differences in electroencephalographic (EEG) activity, together with the fact that meditation is rather a series of dynamic physiological changes than one state, make it hard to draw some general conclusions; some authors are even finding that the process of meditation might be unique to the meditator or that the essential information is not carried by the frequency component of the EEG, and others label the data as ‘confusing’ (Austin, 1999). Dunn et al. (1999) identify two reasons for such incoherent findings in (1) the multifacet character of meditation techniques, when most of them require participants to relax and/or combine both concentration and mindfulness strategies, and (2) different recording techniques utilized by various investigators, which make comparison of results among studies difficult.

Dunn et al. (1999) found in their comparison of relaxation, concentration, and mindfulness meditation that relaxation produces greater mean amplitude at lower frequency bands, delta and theta, than both the concentration and receptive meditation. When relaxation compared to concentrative meditation there were found differences across entire cortex, when compared to mindfulness there were obtained differences across the central/anterior cortex. In contrast at higher frequency bands, alpha and beta-1, an opposite pattern occurred, showing greater activity in parietal and occipital lobes during concentration and in central/posterior cortex during mindfulness meditation. Overall the mindfulness meditation produced relatively more slow (delta and theta) and relatively fast (alpha and beta 1) wave activity than the concentration meditation condition, which can be explained by the mechanism of mindfulness meditation. When the brain is calm and relaxed, it is producing more delta and theta waves, but in mindfulness it is simultaneously awake and alert, producing more alpha and beta 1 activity in central/posterior cortex regions.

As to the neurofeedback, the situation is slightly different. While in meditation research are explored the effects associated with different techniques, neurofeedback research is based on manipulating EEG pattern through different protocols. This principle of course bears some advantages, as to possibility to explore functions of different frequencies on cognitive tasks.

4.1. Alpha Activity

In an overview of over 30 studies Murphy & Donovan (1997) show that the evidence indicating that meditation leads to an increase in alpha rhythms (slow, high amplitude brain waves extending to anterior channels and ranging in frequency from eight to thirteen cycles per second) is extensive. Such conclusion had been reached in studies using many different types of meditation and was confirmed in a review of neuroelectric and imaging studies by Cahn & Polich (2006). There are some studies which report a contrary decrease in alpha activity during meditation (e.g.Warrenburg et al., 1980; Jacobs & Luber, 1989), their dissimilar results are, however, likely to be explained by differences in the initial level of relaxation of subjects.

Banquet (1973) recorded EEG activity in frontal, central, parietal and occipital areas during different stages of TM and found that alpha frequency of about 10 cps and 50 μV was present at resting record of all his meditators and became predominant at the beginning of meditation, with tendency to increase its amplitude and slow the frequency by 1 or 2 cps, first in frontal channels. The same pattern was repeated also at the end of meditation with even grater abundance of alpha waves, the spindles becoming continuous or merging into one another. Travis (2001) recognizes higher EEG alpha amplitude as one of the features which characterize transcending during TM practice, together with lower breath rate, higher respiratory sinus arrhythmia levels, and higher EEG coherence[21]. In a previous study on the difference between meditation and rest (Travis & Wallace, 1999) was found significantly higher anterior–posterior and frontal alpha coherence in meditation, but no differences in alpha power estimates were established; these results are suggesting that TM practice may be best distinguished from other conditions through autonomic and EEG coherence patterns, rather than EEG power" (Travis & Wallace, 1999, p. 311). As described above, relaxation produces slower waves of delta and theta, while meditation can be distinguished by characteristic pattern of faster alpha and beta waves; when more alpha activity occurs during the early phases of meditation, it doesn't mean that subjects are idling mentally, in fact the reverse is true, for attention does facilitate alpha rhythms (Austin, 1999). Alpha persistence is dependent on complexity of the task in concern; it persists during tasks that can be performed easily or automatically. Accordingly alpha waves occupy some 50 percent of the record when experienced Soto Zen monks are engaged in their walking meditation, kinhin. In contrast, alpha waves occur only about 20 percent of the time in inexperienced practitioners" (Austin, 1999, p. 88).

Alpha desynchronization (suppression) is one of the best known EEG phenomenona. Synchronization in the alpha frequency range is taken to be marker of cognitive inactivity, active inhibition of sensory information, or a means of inhibition of non-task relevant cortical areas. There is evidence supporting alternative interpretation which posits that higher alpha power signifies higher readiness of alpha system to information processing, or alertness (Knyazev, Savostyanov, & Levin, 2006). Since the beginning of EEG research it was suggested that alpha suppression reflects attentional processes (Ray & Cole, 1985; Klimesch et al., 1998), a believe that was impugned by evidence indicating that different frequency band within the extended alpha frequency range reflect quite different cognitive processes (Klimesch, 1996), upper alpha desynchronization (10,5-12,5 Hz) being selectively associated

[21] **EEG coherence** is "a large-scale measure which depicts dynamic functional interactions between electrode signals. Higher coherence between EEG signals recorded at different sites of the scalp hint at an increased functional interplay between the underlying neuronal networks" (S. Weiss & Mueller, 2003).

with the processing of sensory-semantic information (Klimesch et al., 1997; Krause et al., 1997) whereas desynchronization in the broad range of about 6,5-10,5 Hz reflects attentional processes (Klimesch, 1996). Based on several such studies it can be summarized that desynchronization in the lower and medium alpha bands is associated with processes of alertness/vigilance (lowest alpha) and expectancy (medium alpha) whereas desynchronized upper alpha reflects enhanced cognitive processing (Aftanas & Golocheikin, 2001). Moreover, internalized attention is inner-directed and results in alpha synchronization, while external attention is outer-directed and results in alpha desynchronization (Shaw, 1996; Aftanas & Golocheikin, 2001). It was further documented that slower alpha synchronization over the frontal region is negatively correlated with heart rate (HF/LF) and that meditation-enhanced internal attention has therefore an inhibitory effect on sympathetic activity (Takahashi et al., 2005)

Several TM studies have emphasized that meditation leads to periods of EEG coherence. These can last for over forty seconds and involve the alpha, theta, and beta frequencies (Austin, 1999). Travis et al. (Travis, 2001) calculated that EEG coherence over broad cortical areas can be reflected by reduction of 45 possible pairs to four averages: (1) bilateral frontal (F3-F4); (2) frontal-central (F3C3, FzCz, F4C4); (3) central-parietal (C3P3, CzPz, C4P4); and (4) frontal-parietal (F3P3, FzPz, F4P4). Badawi et al. (1984) documented the increased alpha coherence to be more evident frontally, with tendency to correlate with both the clarity of ongoing experience and with a suspension of respiration. Successful meditative experience appears to be mediated by a mechanism which allows switch-off external attention, as is indicated by slower frontal alpha synchronization (Aftanas & Golocheikin, 2001).

In neurofeedback research was found that increase in upper alpha with simultaneous decrease in theta power is positively correlated with the improvement in cognitive performance, concretely on mental rotations (Hanslmayr et al., 2005). This findings support the hypothesis of double dissociation between cognitive performance, EEG frequency (in the theta and upper alpha range), and type of EEG response. According to this suggestion good cognitive performance is associated with large resting power but small test power during task performance, while for theta was found opposite pattern (Klimesch, 1999).

4.2. Theta Activity

Wallace (1970, p. 1753) in his early study of physiological effects of meditation described EEG pattern in the frontal area which was recorded during TM as characterized by large-amplitude alpha waves, by a tendency for the alpha waves to decrease in frequency, and by occasional periods during which alpha activity stops and low-voltage theta activity predominates." Banquet (1973) recorded theta activity (slow waves of 4 to 7 cps) predominating during second stage of meditation, after beginning which was characterized by frontal alpha activity. Within 5-20 min after the onset of meditation short burst of high voltage (up to 100 μV) theta frequency at 5-7 c/sec occurred during 1 or 2 sec, simultaneous at all channels or first in the frontal region. These initial bursts were later followed by longer, rhythmic theta trains which lasted from 10 seconds to several minutes. Then, increasingly rhythmic theta trains became synchronized in both the anterior and posterior EEG leads. The theta pattern shown during meditation was rhythmic, which distinguishes it from more irregular forms of theta activity which occurs during ordinary drowsiness. The end of meditation was characterized by the return of alpha trains and in advanced subjects this alpha, and more rarely theta, waves persisted in the post-meditation period with eyes open.

Topographic EEG mapping confirm that theta together with alpha activity predominate during zazen, after entering a deeper stage of meditation, throughout the frontal and parietal regions (Austin, 1999). Also in other meditation techniques is theta activity connected to deeper stages of meditation. Aftanas & Golocheikine (2001) demonstrate on the model of Sahaja Yoga[22] meditation that theta activity is associated with emotionally positive 'blissful' experience. In their study was blissful state "accompanied by increased anterior frontal and midline theta synchronization as well as enhanced theta long-distant connectivity between prefrontal [PFC] and posterior association cortex with distinct 'center of gravity' in the left prefrontal region" (p. 57). Sensitivity to meditation was in this study connected to this theta coherence between PFC and posterior association cortex, along with less pronounced intra- and interhemispheric coherence decreases over posterior brain regions. Theta power positively correlated (r= +0.44 to +0.55) with intensity of blissful experience in anterior frontal and frontal midline leads. On the contrary, appearances of thought distractions were negatively correlated (r= -0.43 to -0.60) with theta power in anterior frontal, frontal midline, central frontal, and right central regions. Moreover, negative correlation was also observed between thoughts appearance and alpha-1 power in midcentral (FCz, Cz, CPz) and adjacent leads. These results were confirmed in later study, concluding that theta power values correlate positively with positive emotional experiences and negatively with mental activity. The inactivation of the cognitive component in meditative process seems to create context or even prerequisites for the occurrence of a positive emotional experience (Aftanas & Golocheikin, 2002).

Increased alpha and theta EEG power, accompanied by a reduced or enhanced autonomic response to external stimuli, was demonstrated by experienced meditators (Banquet, 1973; Travis, 2001). Theta activity is suggested to be implicated in cognitive and affective states; there is evidence that theta band power increases with the task demand and is related to orienting (Dietl et al., 1999), attention (Kubota et al., 2001), memory (Klimesch, 1999; Jensen & Tesche, 2002), and affective processing mechanisms (Aftanas & Golocheikin, 2001). Frontal midline (Fm) theta rhythm was observed also during nocturnal sleep, most frequently

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[22] **Sahaja Yoga** meditation was developed during the 1970s by Nirmala Srivastava, and is followed and promoted among and by the Sahaja Yoga movement. It aims to enter a state of "thoughtless awareness" – where the practitioner 'purifies' his/her attention, achieving clarity of mind – necessary condition on the way to divine connection and spiritual growth.

in during rapid eye movement (REM) and stage I of non-REM sleep, and there was found relation of Fm theta to dream images, with conclusion that even during sleep it is connected to mental activity (Inanaga, 1998). It was found that perception of emotional stimuli is accompanied by a short-term theta synchronization indexing motivated attention (Aftanas et al., 2002; Aftanas et al., 2003) whereas emotional experience is attended by longer lasting theta synchronization (Crawford, Clarke, & Kitner-Triolo, 1996). Theta band activity in the frontal area is correlated negatively with sympathetic activation which suggests a close relationship between cardiac autonomic function and activity of medial frontal neural circuitry (Kubota et al., 2001).

Also different NFB protocols exist, the general aim is to reduce theta power, simultaneously with increase in some higher frequency range. Decreased theta during cognitive task is related to higher performance, while rest theta power usually shows opposite pattern; that is, higher performance in cognitive tasks is associated with greater theta activity during the rest (Klimesch, 1999; Hanslmayr et al., 2005). However, it seems that the effect of theta decrease in relation to performance enhancement is strictly related to higher frequency range increment, as there wasn't found any evidence that theta decrease alone is followed by improved performance (Vernon et al., 2003). Task-related theta decrease has been associated with many outcomes, from ADD/ADHD improvement to RP in abstaining alcoholics (Othmer, 2003). Theta enhancement was tested in relation to working memory performance, but no significant effects were found (Vernon et al., 2003).

4.3. Beta and Gamma

Some of Banquet's meditators showed definite evidence of faster EEG activity in the beta range. These faster frequencies developed after passing beyond the second stage of meditation characterized by rhythmic theta, and the subjects indicated presence of this third stage by prearranged signal which was corresponding to "deep meditation or even transcendence." During this stage, the meditators' EEGs showed beta activity at 20 cps, at first taking form of intermittent spindle-like bursts interspersed between alpha and theta rhythms, later beta continuously rippled over the surface of the larger slower waves which took over to become slow ongoing background activity (Banquet, 1973).

The amplitude of this beta activity reached relatively high levels of 30 to 60 μV. It appeared first in the left hemisphere from frontal to occipital channels and there were periods of uniformity of frequency, amplitude and wave form in all channels. Spectral array[23] revealed that there were present even faster activities which reached gamma frequencies of 40 cps. In contrast, if there were present faster frequencies, they occurred at several different rates and were not as rhythmic or regular.

[23] The **compressed spectral array** is computerized frequency analysis technique which enables thorough examination and interpretation of EEG recorded over long period of time. Cerebral activity is analysed in three-dimensional display which helps better assessment of dominant frequencies, their distribution and amplitudes.

Third state of meditation was accompanied by muscle relaxation in the submental area. REMs which are characteristic at the beginning of meditation disappeared during deep meditation, as well as involuntary muscle movements. Subjects could perform voluntary movements at any stage of meditation, including deep meditation, and could readily and correctly respond to questions using prearranged signals. This performance, however, did not alter the brain wave pattern of deep meditation.

Another important finding of Banquet's study was observation of the fact that his meditators were not interrupted by external stimuli while in the third stage of meditation. In this deep state the power of outside stimuli was greatly reduced and they couldn't penetrate far enough to change their ongoing electroencephalographic pattern; with no alternation the EEG continued to show a mixture of slow and fast frequencies. Banquet's subject showed during third stage a distinctive pattern: (1) a particular subjective state, (2) prominent fluctuating beta EEG activities, (3) no chin muscle activity, (4) reduced EEG responses to sensate stimuli from the outside, and (5) ability to remain alert enough to communicate by signals (Austin, 1999, p. 90).

Lehmann et al.(2001) observed gamma frequency during different meditative states (visualization, verbalization, self-dissolution and self-reconstitution) and computed centre of gravity for each of these states. They found that electric gravity centre location of visualizing meditation was more posterior and more inferior to the three others; the localizations during the self-dissolution and self-reconstitution meditations were more inferior than during verbalization and that the source gravity centre location during the verbalization was more to the left to visualization, self-dissolution and self-reconstitution. Low resolution electromagnetic tomography (LORETA) was used to illustrate locations of maximal t-values obtained, placing the centre of visualizing meditation in right posterior (inferior) area, in left central (medial) area for the verbalizing meditation, and right anterior (superior) area for the self-dissolution meditation. "The self-reconstitution meditation showed stronger activity than the visualizing meditation near (but much superior) to the left central area of the verbalizing meditation, and stronger activity than the self-dissolution and self-reconstitution meditations near the right posterior and inferior area of the visualizing meditation, conceivably because it involved linguistic as well as visual components" (Lehmann et al., 2001, p. 114). A hypothesis of common sources for gamma and beta-2 band was also tested, concluding that the locations differed significantly, the gamma source being more anterior, right and inferior than the beta-2 source.

Lutz et al. (2004) found differences in gamma band between long-term Buddhist practitioners and control group. Not only that long-term meditators self-induced sustained EEG gamma oscillations and phase-synchrony during meditation, but the gamma band was also present in postmeditation baseline. There were found even differences of gamma activity in initial baseline between the two groups, suggesting that meditation "involves temporal integrative mechanisms and may induce short-term and long-term neural changes" (p. 16369). The greatest initial changes were found over medial frontoparietal electrodes, during meditation the difference increased sharply over most of the scalp electrodes and remained higher than the initial baseline in postmeditation baseline; during meditation were the differences distinct particularly over lateral frontoparietal electrodes.

In general is gamma activity present during arousal which is regarded as a necessary condition of its occurrence. In states of extremely low arousal there is minimal gamma activity whereas increased beta and gamma bands reflect a focused arousal in task-relevant neural circuits during cognitive and emotional involvement (Ray & Cole, 1985; Müller et al., 1999). Because high beta and gamma activity bring about peripheral autonomic responses during mental workload, absence of gamma synchronization point to lower autonomic involvement. In a study of arousal to emotionally negative stimuli there were found differences in gamma activity in controls and experienced meditators. Lower or absent gamma activity in meditators suggest their capability to moderate intensity of negative emotional arousal (Aftanas & Golosheykin, 2005).

Dependent on the aims of treatment, beta can be manipulated in two directions, either the protocol focus to enhance beta power in relation to other frequency range, or to suppress it, again in relation to other frequency range (Leins et al., 2006). In between alpha and beta 1 frequency band we may identify SMR, which is the basic pattern neurofeedback aims to change. SMR is usually enhanced, simultaneously with other frequency suppression. Often, based on the needs, beta is the counterpart of SMR enhancement.

4.4. Overview

Although there are a number of studies on EEG activity during meditation, there are only a few which focus on topography distribution. As specific components of frequency band stand for particular cognitive manifestations, investigating the distribution of EEG bands could help to clarify the psychological dimension of meditation and elucidate how different meditation techniques work and what effect they have. This could further help to concretize the application of different meditation techniques as an alternative treatment method. Most EEG-meditation research concentrates on alpha activity and frontal area which produce the most dynamic results, leaving many questions about other areas and frequency bands. There is an evident need to develop and refine a scheme for investigation of spatial distribution of different EEG bands (Liu & Lo, 2007).

Numerous studies have confirmed the results found by Banquet (1973) which prescribe the main EEG activity during meditation to frontal area with alpha band being the best distinguished frequency in EEG pattern (e.g. Travis, 2001; Aftanas & Golocheikin, 2002). Alpha activity increase is typical for the first stage of meditation and is gradually replaced by theta and beta (gamma) activity in later stages of meditation to become predominant frequency at the ending of meditative session, leaving some rudimentary pattern after the meditation has finished (Banquet, 1973).

Alpha activity was recognized the frequency connected to transcending to deeper meditative states (Travis, 2001) which are generally characterized by theta activity and experience of bliss (Aftanas & Golocheikin, 2001). However, appearance of rhythmical theta activity is not necessarily connected to deeper meditation stages as there are techniques in which theta trains appear only at times (Kasamatsu & Hirai, 1966); deeper stages are rather connected to theta bursts which shoot through rhythmical alpha. There is an evidence coming from Zen studies which link experience of inner light, or bliss, to alpha blocking (Lo, Huang, & Chang, 2003); if rhythmical theta activity is present it is also showing blocking to sensory stimulation (Kasamatsu & Hirai, 1966). Beta and gamma activity were identified in Banquet's study of TM (1973) as the frequencies accompanying the deepest meditative states and were confirmed to be present during meditation of experienced meditators. In Zen studies are beta and gamma frequencies normally missing. These differences confirm findings which suggest that increase in beta and gamma band reflect emotional and cognitive arousal (Ray & Cole, 1985; Müller et al., 1999), condition fulfilled in TM where attention is directed at mantra, and are absent during lower emotional and cognitive responses which form the nucleus of Zen mindfulness meditation.

Apart from the inappropriate mixing of evidence coming from studies of different meditation techniques based on the two distinct forms (concentrative and receptive) there is a problem of deficient knowledge of EEG topography and progression during meditation. Although the research on EEG and meditation has a long tradition, it answers paradoxically very little about meditation-induced physiological processes. There is a need to shape a form which would help coordinate further research and would allow comparison of different techniques. New neuroimaging techniques hold the potency to reorient the EEG study on the processes which were until recently unknown or neglected. Combination of neuroimaging and electroencephalography is desirable not only for the cost-effectiveness and unpretentiousness of EEG but also for their mutual complementation.

1. Introduction

In the recent years there has been apparent interest in the possibilities of performance enhancement training. The aim of such training is for the individual to improve specific qualities, often memory, attention or cognition, by undertaking various programmes. There has been a dramatic increase in the number of claims made that meditation and neurofeedback training can lead up to fewer errors and greater efficiency in psychological tests and tasks, resulting in more positive outcome.

Previous research has documented associations between specific cortical states and optimum level of performance in a wide range of tasks. There are quanta of literature reviewing the positive effect of both, neurofeedback and meditation, on performance. An examination of literature reveals that NFB training has been utilised to enhance performance from three main areas; sport, cognitive and artistic performance (D. J. Vernon, 2005). The areas of application are somewhat similar for both techniques and thence also in the case of meditation we may find analogous listing (Druckman & Bjork, 1991). Some suggestive findings have been reported for both techniques with regard to use in training programmes aiming cognitive and attentional performance enhancement.

Traditionally, performance has been characterised as operating along continuum, where dysfunctional performance is positioned at one extreme and optimal performance is located at the other (Kirk, 2001; D. J. Vernon, 2005). The idea of NFB supporters based on this theory is very simple; changes in performance of those who suffer from various conditions and are located at the dysfunctional end of continuum, should bring them up to normative baseline, and may even enhance the performance of those at the normative baseline moving them closer to the optimal region (D. J. Vernon, 2005).

Currently is research oriented on the long-term effects of both techniques; experienced meditation practitioners claim years of practice and cumulative effect of meditation training, NFB experts give evidence that the first signs of training benefits are observable somewhat after 20 sessions, effective treatment for ADD/ADHD symptoms usually requiring between 20 and 40 sessions (Othmer, 2003). However, some orthodox proponents of NFB claim that it is possible to observe some training effects after as few as eight sessions and that in individuals positioned at the normative baseline, that is, normal healthy individuals, such procedure eventuate in improvement of cognitive and attentional performance (D. Vernon et al., 2003). Similarly, proponents of meditation claim that in normal healthy subjects given five days of meditative training, there was improvement in attentional performance (Tang et al., 2007).

Specific EEG patterns were distinguished to be underlying concentrative and mindfulness meditation (Dunn, Hartigan, & Mikulas, 1999). In the QEEG research there have been identified frequencies and patterns related to some mental tasks, and extensive correlation of EEG analysis with psychological tests is still in progress (Faber, 2005). The research on neurofeedback and meditation has led to conceptualizations of both techniques as mechanisms that may be used to stimulate and possibly regulate cerebral activity. However, the evidence suggesting, that giving training to enhance particular frequency or inhibit another will specifically influence cognitive performance, remains insufficient.

Number of studies claims that enhancement of SMR activity (12-15 Hz) and simultaneous inhibition of theta (4-7 Hz) and beta (18-22 Hz) positively influences attention (Lubar, Swartwood, Swartwood, & O'Donnell, 1995; Rossiter & La Vaque, 1995); and the rhythm was also identified to influence performance on a semantic working memory task and to some extent focused attention (D. Vernon et al., 2003). Greater beta-2 (18.5-30 Hz) amplitude in posterior sites was identified as a specific component of mindfulness and concentrative meditation (Dunn et al., 1999) and on animal model was suggested to be positively correlated with visual attentive tasks (Wróbel, Ghazaryan, Bekisz, Bogdan, & Kamiński, 2007). There is also evidence that higher performance in cognitive tasks is related not only greater amplitude in specific frequency bands but also to desynchronization in associated cortical areas (Thatcher et al, 2005). On the other hand, neurofeedback training and meditative techniques that are suggested to enhance performance in cognitive tasks have also been documented to conduce to greater coherence between task-related areas, and when in rest (Vernon et al., 2003).

The aim of this study is to certify the hypotheses proposed in the studies mentioned above, that is, that short-term neurofeedback/meditation training has effect on cognitive and attentive processes in normal healthy adults and that such training lead to performance enhancement.

With a view to investigate the possibility we initially examined several cognitive and attentional attributes, specifically working memory, spatial orientation, visuo-spatial subsystem within the short-term memory (memory span), long-term selective attention, reaction time, reading and naming interference. After this inaugural performance testing at time-1 were our healthy adult subjects divided into three groups, using semi-randomization. First group undertook two-week extensive neurofeedback training and were required to enhance their SMR activity (12-15 Hz), simultaneously inhibiting theta (4-7 Hz). Second group undertook two-week concentrative meditation training, which was previously reported to increase/decrease activity in frequency bands similar to those of SMR activity neurofeedback training (Dunn et al., 1999). Third group acted as controls, completing both, the performance testing at time-1 and time-2, which occurred immediately after the two-week training of first two groups, but not participating at NFB nor meditation sessions. Together with performance in the cognitive and attentive tasks there were recorded EEG data in the two groups, again, at time-1 and time-2, to estimate possible changes in EEG coherence induced by the training. The global numeric values for coherence in RELAX states obtained in nby spectral analysis for pre and post recordings were correlated with the test results, both at time-1 and time-2.

2. Methods

2.1. Subjects

Fifteen healthy adult participants, at that time undergoing complex rehabilitation of various locomotive problems in military rehabilitation centre in Slapy nad Vltavou, were recruited using leaflet information about the project. Before enrolment in the programme, their health condition and suitability had been checked in the database of their medical history. Based on this screening and short interview that followed, three individuals were declined as incompatible with the study; 1 for psychiatric condition in the family anamnesis (possibly some sort of affective disorder), 1 for having bleeding in the brain in her anamnesis and 1 for having serious head injury and subsequent operation in the childhood. Although in both cases the head injury happened before the age of 12 and consecutive examinations, including EEG recording (in one case SPECT) have displaced any consequences, they were better screened out from further investigation. As we had only 13 suitable participants who volunteered for the programme, we asked them for help to recruit remaining two. Current formation consisted of 7 men and 6 women, so we were preferably looking for 2 men to make the future allocation in the groups more homogenous. Thanks to our volunteers we managed to enrol two more men.

The age limits established prior to the study were 22 and 50 years; reasons for such selection were based on nervous system maturation. There is sufficient evidence that documents brain maturation in adolescent and post-adolescent brain, with frontal areas, that play crucial role in cognitive processing, being developed only in young adulthood (Sowell, Thompson, Holmes, Jernigan, & Toga, 1999). On the contrary, after the age of 50, human cognitive processes dramatically deteriorate (Verhaeghen & Salthouse, 1997), and even though the age between 20 and 50 years is not as stationary as once thought, changes in cognition are not so rapid (Schroeder & Salthouse, 2004).

A total of 15 subjects were recruited to participate in this study, 6 females and 9 males, with average age of 37,1 years (SD=10 years, range 24 – 50 years). They all were free of cardiac, pulmonary, metabolic and other diseases that could cause autonomic system dysfunction. Among the subjects there were three light smokers (max. 10 cigarettes/day), one left-handed person and none habitual drinker. None of the participants was at the time of study taking any medication. No participant had previously practiced any form of meditation technique or had experience with neurofeedback. Informed written consent was obtained from each subject after the experimental procedures had been explained.

In the next step were the participants allocated to one of the three groups – neurofeedback (NFB), meditation (MED) and control (CNTRL) – by semi-randomization. We were aware that the groups should be as homogenous as possible. We decided to form groups of five subjects, 3 males and 2 females, and one smoker in each of the groups. Other characteristics, such as hand dominance, age or education, were from the standpoint of the research design considerate as important. After these premeasures were the subjects randomly divided into the groups. Only by chance, the groups were quite consistent as to education; however, the average age among the groups differed (

Report

Age

Experimental Group	Mean	N	Std. Deviation	Median	Minimum	Maximum	Variance	Skewness
NFB	33,320	5	9,8304	31,300	24,4	49,5	96,637	1,433
MED	41,180	5	11,5874	49,200	27,9	50,1	134,267	-,611
CNTRL	36,960	5	8,9531	35,300	28,1	47,2	80,158	,250
Total	37,153	15	9,9963	34,400	24,4	50,1	99,927	,274

Table II. Age means for the experimental groups

Case Summaries[a]

				Respondent	Sex	Age	Hand Dominance	Education	Smoking
Experimental Group	NFB	1		1	Female	49,5	Right	University	Non-smoker
		2		2	Male	24,4	Right	University	Non-smoker
		3		3	Female	31,3	Right	A-levels	Non-smoker
		4		4	Male	27,0	Right	A-levels	Smoker
		5		5	Male	34,4	Right	A-levels	Non-smoker
		Total	N	5	5	5	5	5	5
	MED	1		6	Male	27,9	Right	University	Smoker
		2		7	Female	49,2	Right	University	Non-smoker
		3		8	Male	50,1	Right	A-levels	Non-smoker
		4		9	Male	29,1	Right	University	Non-smoker
		5		10	Female	49,6	Right	A-levels	Non-smoker
		Total	N	5	5	5	5	5	5
	CNTRL	1		11	Female	47,2	Right	A-levels	Non-smoker
		2		12	Male	45,3	Right	University	Non-smoker
		3		13	Male	28,9	Left	University	Smoker
		4		14	Female	28,1	Right	University	Non-smoker
		5		15	Male	35,3	Right	A-levels	Non-smoker
		Total	N	5	5	5	5	5	5
	Total	N		15	15	15	15	15	15

a. Limited to first 100 cases.

Table III. Experimental groups descriptive statistics

2.2. Procedure

Before the procedure, all the participants were shown the testing room, and were introduced the computer interface as all the tests, but one, were computerized. They also had trial go on the computer to prevent eventual error of bias for one of the tests was performed on a touch screen. Subjects were instructed to rest and to have at least eight hour sleep the night precedent to the testing. They were also asked not to consume alcohol and stimulant beverages at least 12 hours before the testing. They were asked to refrain from eating and drinking for at least 2 hours prior to the experiment.

Testing situation consisted of psychological evaluation and EEG recording. Execution time of psychological tests was dependent on the performance of each participant and in no case lasted longer than 60 minutes. After psychological evaluation the participants took 5 minutes break and after that EEG data were recorded. EEG recording followed the psychological testing to avoid unnecessary tension during the session. Recording itself took 10 minutes at time-1 (before the training) and 6 minutes at time-2 (after the two-week training). Again, first recording was longer so that the participants could adapt to this new situation. After having first experience it was possible to make second session shorter.

Performance testing at time-1 ran from May 13 to May 22, 2009, that is one week. The testing took place in the afternoon hours (from 3 to 5.30 p.m.) and only two subjects per day were tested. Between the tests there were one minute breaks to relax eyes and possibly ask questions. Instructions were given by the computer and repeated verbally to assure comprehension. Performance testing was followed by EEG recording. While the cap was being fitted, the participants were explained some features of electroencephalography and were instructed how to rest to avoid muscular and ocular artefacts. After they were fitted with cap, they were shown their brainwaves on the monitor and were instructed about recording task sequence.

After data collection, NFB and MED groups were given two week (10 sessions) training. NFB group took their training from May 25 to June 5, 2009. MED group took their training from June 1 to June 12, 2009. Performance testing at time-2 ran from June 8 to June 12, 2009 for NFB and CNTRL group. NFB group was on June 8 and 9, 2009, to avoid wear-off of possible effects. MED group was tested following week on July 15 and 16, 2009. Testing procedure at time-2 was coequal to time-1.

2.3. Psychological Testing

To evaluate participant’s performance in cognitive tasks, we used Vienna Test System (VTS) version 6.52.018 computerized psychological assessment tool. The use of the computer ensures higher level of objectivity and precision and allows testing some features which are difficult to control or that couldn’t be measured by traditional paper-and-pencil tests. An advantage is also its easy administration.

The following tests and subtests were administered, in the sequence hereby introduced (as presented by Schufried GmbH (2009)):

SIGNAL (S1) – 14 minutes – Test is based on signal detection theory and evaluates performance in the visual detailed registration of complex stimuli under time pressure over a long period of time. Test assesses long-term selective attention by measuring the visual differentiation of a relevant signal within irrelevant background. The main variables calculated are the numbers of correct, delayed and incorrect reactions as a measure of the reliability of the detection process, and the median detection time as a measure of the speed of the detection process. For the variable "number of correct and delayed reactions" split-half reliability coefficients (odd-even method) of between r=0,74 and r=0,85 were obtained, depending on the test form and the comparison sample. For the median detection time the reliability calculated by the same method was between r=0,78 and r=0,84.

3D – 3 minutes – Spatial Orientation, as an important factor of intelligence tests, is assessed in non-verbal test of mental visualization and the ability to apply transformations to objects in three-dimensional space. The number of correctly worked items is taken as the measure of spatial ability. Both raw scores and percentile ranks are reported in the results protocol. The split-half reliability coefficients vary between 0,82 and 0,87 for respondents of different educational level.

RT (S1) – 3-4 minutes – Reaction Test assesses reaction time (split into reaction and motor time) in response to simple and complex visual or acoustic signals. They also identify attention disorders, assess the ability to suppress inappropriate reactions and provide intermodal comparisons. The following main variables were calculated: mean reaction time and mean motor time, measure of dispersion reaction time and dispersion motor time.

Reliabilities (Cronbach's alpha) in the norm sample vary between r=0,83 and r=0,98 for reaction time and between r=0,84 and r=0,95 for motor time.

CORSI (S1) – 10-15 minutes – Corsi Block-Tapping Test measures visual short-term memory capacity and operationalises the visuo-spatial memory span. It indicates the longest sequence length that has been reproduced correctly at least once. The reliability of the test is between r=0,81 and r=0,89.

STROOP (S8) – 10-15 minutes – Stroop Interference Test provides fair and highly reliable assessment of the ability to inhibit overlearned answers to simple tasks. Test subtest differentiates between congruent items - colour and meaning of the word match - and incongruent items - colour and meaning of the word DO NOT match. The main variables are reading interference and naming interference; the execution time is also measured.

PASAT-50 (paper-and-pencil) – 4 minutes – The Paced Auditory Serial Addition Test is a measure of cognitive function that assesses auditory information processing speed and flexibility, as well as calculation ability. The test evaluates working memory and sustained attention. There was documented split-half reliability greater than r=0,9 and test-retest reliability values of 0,93-0,97 (Mitrushina, Boone, Razani, & D'Elia, 2005).

Based on the performed tasks, 11 variables were designated. The raw scores obtained in particular tests were automatically converted into T-scores on the basis of comparison with calibrated Austrian norm sample. In the case of PASAT-50, as Czech norms were not available, the raw scores were converted into T-scores using a formula introduced by Diehr et al. (1998; 2003); 12,93 + (4*Scaled Score) + (0,23*Age) - (1,06*Education). As for different educational systems in the Czech Republic and the United States, two-year college was equivalent to A-levels secondary school, four-year college to a bachelor's degree and master's/engineer degree were coequal.

TEST	VARIABLES
SIGNAL	Signal Detection
3D	Spatial Orientation
RT	Reaction Time
	Motor Time
	Dispersion Reaction Time
	Dispersion Motor Time
CORSI	Corsi Block-Tapping Test
STROOP	Reading Interference
	Naming Interference
	Stroop Test Time
PASAT-50	Pace Auditory Addition Task

Table IV. Variables

PASAT Time-1 results		PASAT Time-2 results	
Raw score	T-score	Raw score	T-score
44	49	45	53
44	46	48	58
48	61	47	57
42	48	42	48
39	42	42	46
43	44	45	48
49	65	48	61
46	58	48	66
47	55	48	59
44	54	45	58
41	49	41	49
42	48	41	44
49	61	48	57
45	47	44	46
44	50	44	50

Table V. Pasat T-score table

2.4. EEG Recording

Each participant was measured the head size and was fitted with a correspondent (small, medium, large) Electrocap™ containing 20 electrodes nine mm in diameter. Nineteen electrodes were active and were referred to linked earlobes (monopolar recording). Site Fpz served as ground. All placements were in accordance with the International EEG nomenclature – the International 10/20 system (Jasper, 1958; Klem, Lüders, Jasper, & Elger, 1999,).

All recordings were made using preamplifiers with set amplification A=1, entry impedance min 100 Mohm//10 pF and low and high frequency cutoffs being set at 0,15 Hz and 120 Hz, respectively, coupled to a modular digital EEG amplifier EADS220 BrainScope. The data were simultaneously stored on a magnetic optical disk for offline analysis.

While being fitted with the cap, the participants were shortly described the principles of EEG recording and were answered eventual questions. In preview mode they were shown EEG registration and were instructed about how to minimize appearance of muscular and ocular artefacts. After that the participants were instructed to lie in a supine position on the medical couch and to calm their respiration rate. In time-1 the registration ran in following sequence: 2 minutes eyes open (OA), 2 minutes eyes closed (OC), 2 minutes OA, 2 minutes OC, 2 minutes relaxation with eyes closed (RELAX). In time-2 the registration followed this sequence: 2 minutes OA, 2 minutes OC, 2 minutes RELAX.

2.5. Neurofeedback training

NFB group was given 30 minutes training for the period of 10 days (5 hours). One session consisted of 15 rounds of 2 minutes. Training of such extent is quite demanding for neurofeedback beginners and it is common that first sessions begin at about 11 rounds. To avoid exhaustion, the participant regulated the breaks between rounds according to their needs. Normally there were about 10 to 30 second pauses. The participants had each specific time to conduct the training; overall the training took place from 2.45 to 5.40 p.m. There were some problems concerning the environment as the training room was not air-conditioned and there were also some disturbing external noises from the corridor behind the door. Sometimes it could be observed on the performance that the participants were occasionally disturbed; however, such disturbances didn’t have long-term effect and usually were indicated by only momentary drop in their attention and resulting decrease in the performance.

The training was conducted on EEG apparatus and NFB machine BrainScope and was adjusted to increase SMR and decrease theta activity, which was documented to be associated with attention enhancement, as mentioned above. There was evident progress in the performance of the participants but it couldn’t be registered in graphic form due to system error. However, registry files showing numeric computation of performance level revealed rapid increase after first few sessions, followed by only small improvements or stable performance (from about 6th session). The difficulty of the task was regulated according to the actual performance, which tended to decrease at the end of the session due to demanding nature of the training and its unusual length (from about 12th-13th round).

2.6. Meditation training

Like in the case of NFB group, the meditation group was given 30 minutes training for the period of 10 days (together 5 hours of meditation). Because all the participants were beginners, with no previous experience with meditation or relaxation, it was necessary to choose some easy form of concentration meditation, as mindfulness meditation is not very appropriate for inexperienced meditators and takes years of practice to master. It was desirable to choose such technique that would be easy to learn and which would have characteristics similar to those of neurofeedback SMR training.

Since Andrew and Mathews published their EEG study in 1934, there has been explored the possibility to use light stimulation as a form of therapy that could alter subject’s brain activity (Pigott, Alter, & Marikis, 2008). The effects of light have been documented in several studies and it was suggested not only to have synchronising outcomes (e.g. Frederick, Lubar, Rasey, Brim, & Blackburn, 1999; Pigeau & Frame, 1992), but also that this effect persisted during mental task performance and could lead to performance enhancement (Budzynski, Jordy, Budzynski, Tang, & Claypoole, 1999). Several studies have claimed that light stimulation neurotherapy has effects comparable to those of neurofeedback and meditation and could be successfully applied to similar range of conditions (Pigott et al., 2008).

For the proposed effects of light neurotherapy we decided to employ the element of light in our meditation technique. As it needed to be concentrative technique, we decided to go with yogic trataka meditation, or candle gazing, which fulfils the condition of easy mastery and fast progress. The aim of trataka is to develop concentration and mental focusing by gazing steadily at some small object without blinking until the eyes strain and water, often, as in our case, the object being a candle flame. Trataka with open eyes is followed by visualization of the object; it is, calling up of a clear mental image. After mental image of object becomes less clear, eyes are open again till lachrymation manifests. For our purposes, to ensure acquirement of right breathing pattern, trataka was accompanied with OM mantra. The participants were instructed and exercised how to inhale and exhale, OM mantra being repeated mentally with every breath in and aloud with every breath out.

Meditation training took place every work day from 5.45 to 6.15 p.m. The room in which training took its course served as cinema auditorium and offered ideal conditions for our purposes. The room was isolated from external noise and was air-conditioned, with temperature set at 22°C (72°F). As some of the participants had locomotive problems that prevented them from assuming lotus position, we decided to use cinema chairs instead. Each participant had its candle which was placed in approximately 90 cm distance (arm-length), at eye level.

As some of the participants wore glasses, they were instructed to take them off during meditation, so that they didn't damage their retina. As we practiced group meditation and pronounced OM mantra could disturb the participants, they were provided with sanitary earplugs which helped them concentrate. Participants were also instructed to immediately report any adverse effects or disagreeable feelings that would occur during and after the fortnight meditation training. However, the only problem reported was uncomfortableness caused by assumed position in one case, which disappeared after two sessions.

2.7. Statistical analysis

Statistical analysis was carried out using SPSS software for Windows, version 15. At the first step, intergroup means were compared using the boxplot charts. There were observed some differences suggesting that the performance of the groups were differing. It was necessary to compare the means and find if the groups were similar as to their performance, or if the differences were significant. For the small number of participants it was unreasonable to use statistics based on the assumption of normal distribution. Therefore, nonparametric tests were employed. The groups were compared by Kruskal-Wallis Test to ensure similarities in cognitive performance, the test was ideal as the data were unpaired, non-Gaussian, and the shapes of distribution were similar. Following this, we used Wilcoxon Signed Rank Test to test the hypothesis of performance enhancement in paired small samples. Both statistics is possible to apply on small samples. Kruskal-Wallis ANOVA is applicable as total sample size n>7, the samples are the same size, number of groups k>2 (Motulsky, 2007), and as there are at least five scores at each sample, it is not necessary to compare H values with Kruskal-Wallis Statistic Tables to determine the significance level, but is possible to use chi-square probabilities (Ho, 2006). Wilcoxon Signed Rank Test (WSRT) was used for within-subjects design of interval data obtained from the same individuals, the distributional assumptions were suspect, the total sample size was small and number of within-group subjects wasn't lower than 5, hence testable at significance level (Ho, 2006).

2.8. EEG analysis

EEG analysis was conducted in WaveFinder module program for Windows, version 1.31. At first, all the records were checked for signs of possible abnormalities that would exclude participant from the experiment. As all the records seemed normal, they were all included in the study. After that, the data were visually scanned for any epochs with movement, electrode or eye-movement artefacts were manually marked and were excluded from further analysis. Furthermore, the eye-movement artefacts were also controlled by software pre-settings.

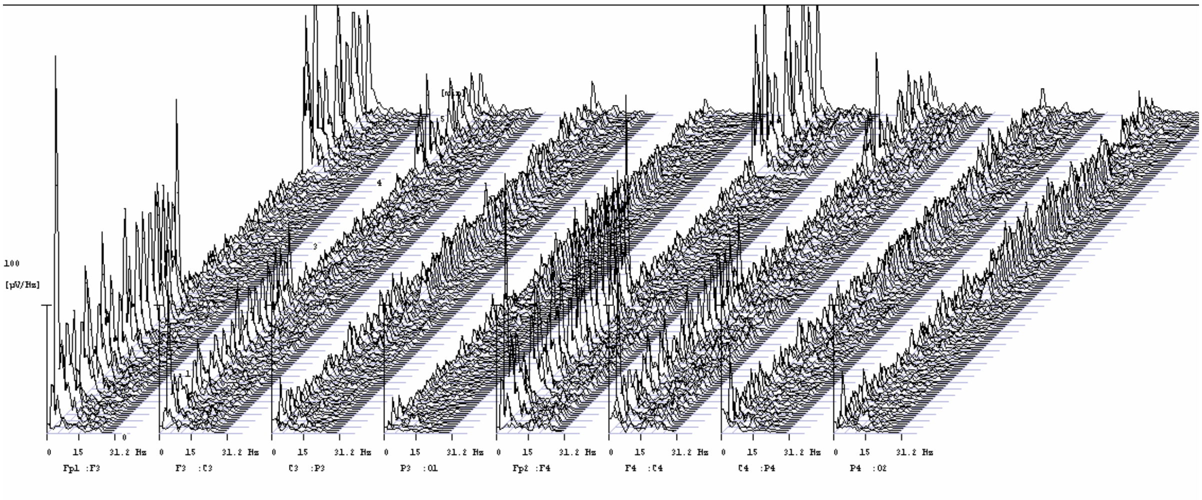


Image III. Eye-movement artefacts visible mainly in the frontal areas (OA)

Three different states (OA, OC, RELAX) recorded during the sessions were analysed using electroencephalospectrograms (ESG) obtained by fast Fourier Transformation (FFT) and constructed into BEAMs.

At next step, interhemispheric coherence was computed for RELAX at time-1 and time-2 and the maps were compared for each participant. Global coherence values in longitudinal direction were calculated for eight coherence pairs: Fp1-F3, Fp2-F4, F3-C3, F4-C4, C3-P3, C4-P4, P3-O1, P4-O2. The numeric values were than correlated with test results for each of the two measures.

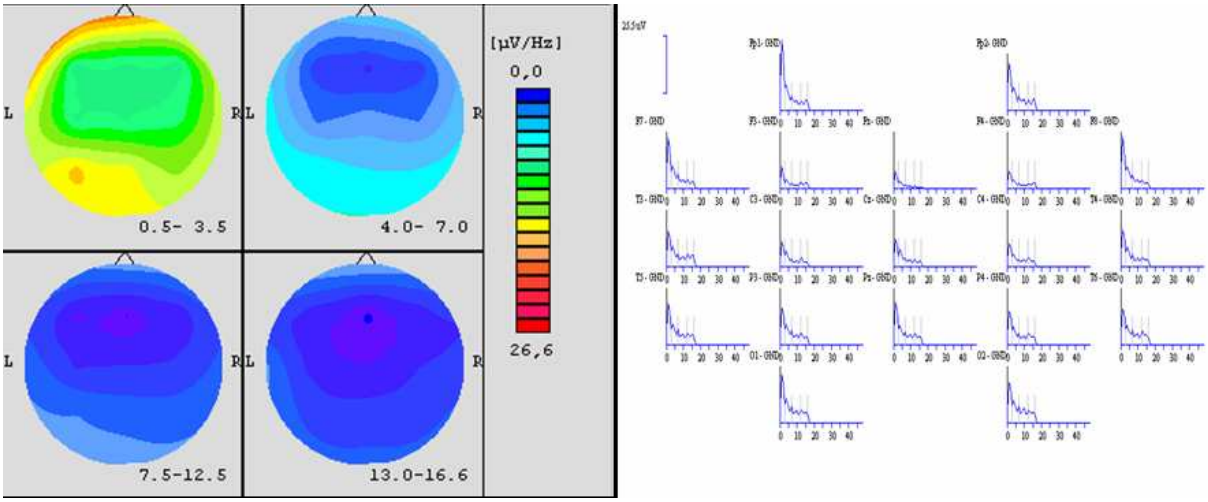
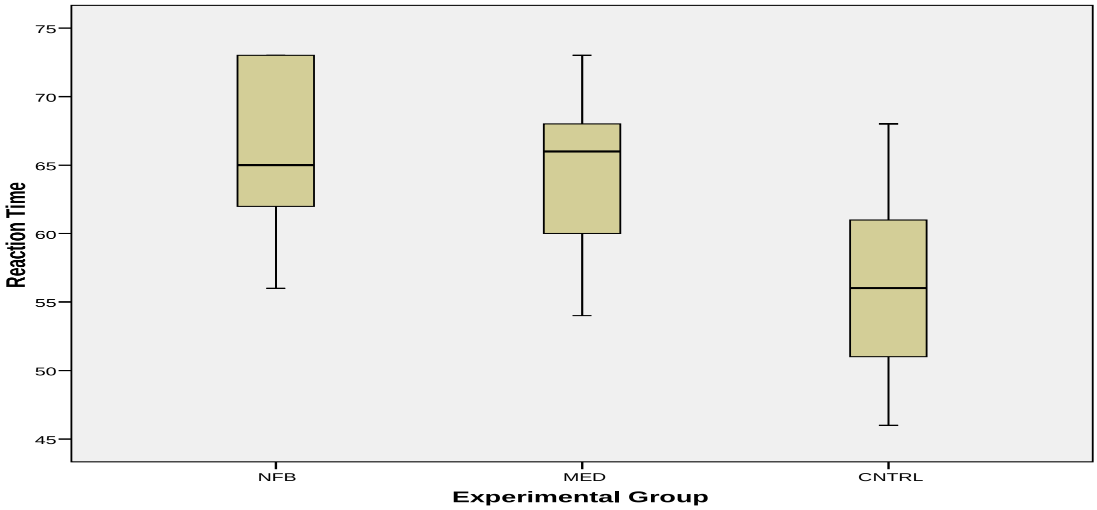


Image IV. BM and ESG for OA

3. Results

3.1. Performance enhancement

Boxplot charts for all the variables were checked before any statistic was conducted, to ensure performance similarities of the three samples in time-1. The charts suggested some differences in the means but the groups were roughly similar.



3.1.1. Kruskal-Wallis ANOVA

Ranks

	Experimental Group	N	Mean Rank
Signal Detection	NFB	5	6,90
	MED	5	10,70
	CNTRL	5	6,40
	Total	15	
Spatial Orientation	NFB	5	5,50
	MED	5	9,60
	CNTRL	5	8,90
	Total	15	
Reaction Time	NFB	5	9,90
	MED	5	8,90
	CNTRL	5	5,20
	Total	15	
Motor Time	NFB	5	8,20
	MED	5	10,60
	CNTRL	5	5,20
	Total	15	
Dispersion Reaction Time	NFB	5	7,60
	MED	5	9,20
	CNTRL	5	7,20
	Total	15	
Dispersion Motor Time	NFB	5	7,50
	MED	5	10,00
	CNTRL	5	6,50
	Total	15	
Corsi Block-Tapping Test	NFB	5	7,00
	MED	5	10,90
	CNTRL	5	6,10
	Total	15	
Reading Interference	NFB	5	8,10
	MED	5	8,40
	CNTRL	5	7,50
	Total	15	
Naming Interference	NFB	5	9,40
	MED	5	5,80
	CNTRL	5	8,80
	Total	15	
Stroop Test Time	NFB	5	6,60
	MED	5	6,60
	CNTRL	5	10,80
	Total	15	
Pace Auditory Addition Task	NFB	5	6,30
	MED	5	10,00
	CNTRL	5	7,70
	Total	15	

Table VI. Kruskal Wallis Ranks

$$H_0: M(NFB) = M(MED) = M(CNTRL)$$
$$H_a: \text{non-Ha}$$

The assumption of variable differences between groups based on the boxplot charts was correct. In the Ranks table there can be observed mean differences as obtained for particular tasks. In several variables (signal detection, motor time, dispersion reaction time, dispersion motor time, CORSI, PASAT) the MED group shows the highest values, suggesting that the group consisted of individuals that performed slightly better than individuals in two other groups. The H (χ^2) statistics for each variable were compared against critical value tables (see k = 3, α = 0,05); for none of the variables the computed H value is greater than $\chi^2_{.05} = 5,78$, and the alternative hypothesis for neither of the variables is supported at the 0,05 level of significance. As the asymptotic significance values for particular variables shown in Test Statistics chart are higher than 0,05 significance level, we fail to reject the null hypothesis. A Kruskal-Wallis test revealed that at α = 0,05 significance level, the three groups (NFB, MED, CNTRL) are similar as to their median performance in cognitive tests measured at time-1.

Test Statistics[a,b]

	Signal Detection	Spatial Orientation	Reaction Time	Motor Time	Dispersion Reaction Time	Dispersion Motor Time	Corsi Block-Tapping Test	Reading Interference	Naming Interference	Stroop Test Time	Pace Auditory Addition Task
Chi-Square	2,795	2,414	3,098	3,680	,572	1,743	4,249	,106	1,894	2,940	1,748
df	2	2	2	2	2	2	2	2	2	2	2
Asymp. Sig.	,247	,299	,212	,159	,751	,418	,119	,948	,388	,230	,417

a. Kruskal Wallis Test

b. Grouping Variable: Experimental Group

Table VII. Kruskal Wallis statistics

3.1.2. Wilcoxon Paired Signed-Rank Test

Symmetric assumptions were checked before conducting the statistics. Time-1 and time-2 differences were computed. Again, boxplot charts suggested rough symmetry assumption for main variables. However, some variables didn't meet the criteria and were highly asymmetric. These should be excluded from further analysis as they do not meet symmetry assumptions necessary for Wilcoxon Paired Rank Test. However, just out of curiosity, they were included in the pre-post comparison, but no conclusions were drawn. Namely they were dispersion reaction time, dispersion motor time, STROOP time (additional variables not important for overall test results), and PASAT (Image VI.).

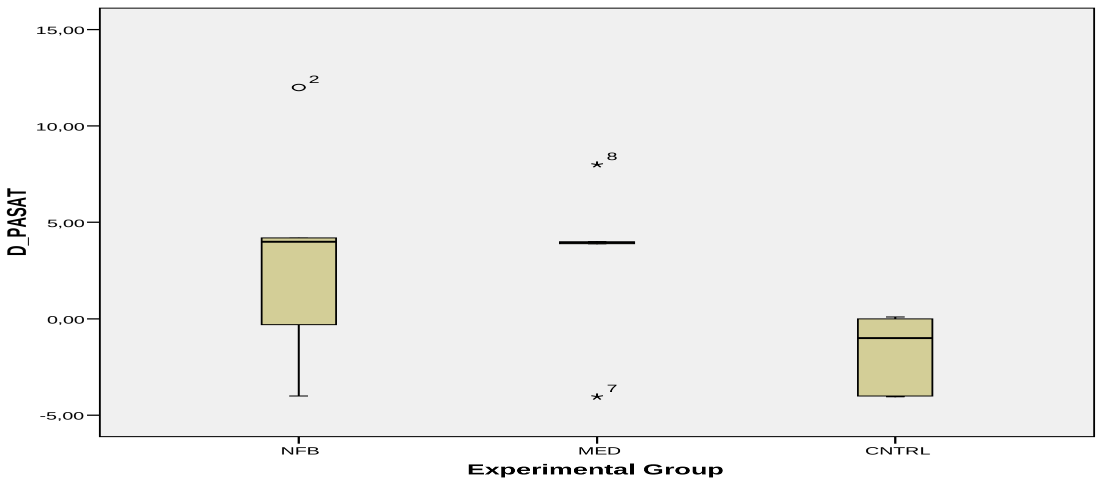


Image V. PASAT boxplot charts

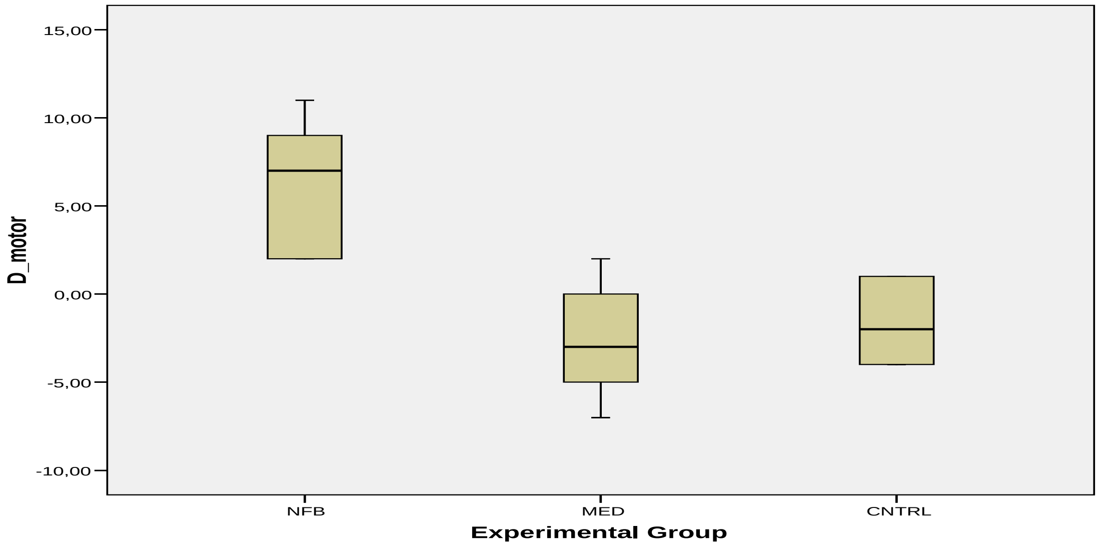


Image VI. Boxplot charts for dispersion motor time

3.1.2.a Neurofeedback

A Wilcoxon Signed Rank Test for NFB group revealed that there were some differences between performance measures at time-1 and time-2. Overall group performance in most tasks was better at time-2, with exception of signal detection that showed higher performance results at time-1.

$$H_0: \mu_{time\text{-}1} = \mu_{time\text{-}2}$$
$$H_a: \mu_{time\text{-}1} < \mu_{time\text{-}2}$$

Because the sample was very small (n = 5), before drawing any conclusion, it was necessary to compare the T statistic for each variable with critical value tables of one-tailed WSRT. Critical value for one-tail WSRT for n =5 is 0 (1), which was exceeded in some of the variables (Table VIII.).

It can be concluded that Wilcoxon Signed Rank Test revealed statistically significant reduction of motor response time in Reaction Test following participation in neurofeedback training program, $z = -2{,}032$, $p = 0{,}021 < 0{,}05$, $T = 0$, $n_{(5-0)} = 5$. The mean percentile of motor response time increased from pre-training 61,20 to post-training 67,40; also reaction time in Reaction Test shows statistically significant reduction in response (p-value = 0,021, T = 0), at 0,05 level of significance we accept the alternative hypothesis that NFB training participation led to reduction in reaction time, with mean percentile of reaction response increasing from pre-training 65,80 to post-training 70,20. Since signal detection (SIGNAL) test p-value = 0,137 > 0,05 and T = 8, we fail to reject the null hypothesis; at the level α = 0,05 of significance, there is not enough evidence to conclude that NFB training led to better performance in the test. Spatial orientation (3D) p-value = 0,021 < 0,05, T = 0; WSRT revealed statistically significant performance enhancement in 3D task following participation in neurofeedback training, the mean percentile increased from pre-training 51,00 to post-training 61,00. For reading interference and naming interference in STROOP task the p-values are 0,072 and 0,051, respectively. Although the T values were 1 and 0, respectively, we fail to reject the null hypothesis. At the level $\alpha = 0{,}05$ of significance, there is not enough evidence to conclude that following NFB training led to better performance in STROOP task. CORSI revealed significant performance enhancement (p-value = 0,042 < 0,05, T = 0); this change, however, wasn't supported due to ties $n_{(5\text{-}2)} = 3$.

Ranks

		N	Mean Rank	Sum of Ranks
Signal Detection Retest - Signal Detection	Negative Ranks	3[a]	2,67	8,00
	Positive Ranks	1[b]	2,00	2,00
	Ties	1[c]		
	Total	5		
Spatial Orientation Retest - Spatial Orientation	Negative Ranks	0[d]	,00	,00
	Positive Ranks	5[e]	3,00	15,00
	Ties	0[f]		
	Total	5		
Reaction Time Retest - Reaction Time	Negative Ranks	0[g]	,00	,00
	Positive Ranks	5[h]	3,00	15,00
	Ties	0[i]		
	Total	5		
Motor Time Retest - Motor Time	Negative Ranks	0[j]	,00	,00
	Positive Ranks	5[k]	3,00	15,00
	Ties	0[l]		
	Total	5		
Dispersion Reaction Time Retest - Dispersion Reaction Time	Negative Ranks	0[m]	,00	,00
	Positive Ranks	4[n]	2,50	10,00
	Ties	1[o]		
	Total	5		
Dispersion Motor Time Retest - Dispersion Motor Time	Negative Ranks	1[p]	2,00	2,00
	Positive Ranks	3[q]	2,67	8,00
	Ties	1[r]		
	Total	5		
Corsi Block-Tapping Retest - Corsi Block-Tapping Test	Negative Ranks	0[s]	,00	,00
	Positive Ranks	3[t]	2,00	6,00
	Ties	2[u]		
	Total	5		
Reading Interference Retest - Reading Interference	Negative Ranks	1[v]	1,00	1,00
	Positive Ranks	3[w]	3,00	9,00
	Ties	1[x]		
	Total	5		
Naming Interference Retest - Naming Interference	Negative Ranks	0[y]	,00	,00
	Positive Ranks	3[z]	2,00	6,00
	Ties	2[aa]		
	Total	5		
Stroop Retest Time - Stroop Test Time	Negative Ranks	4[bb]	2,75	11,00
	Positive Ranks	1[cc]	4,00	4,00
	Ties	0[dd]		
	Total	5		
Pace Auditory Addition Re-task - Pace Auditory Addition Task	Negative Ranks	2[ee]	1,75	3,50
	Positive Ranks	3[ff]	3,83	11,50
	Ties	0[gg]		
	Total	5		

Table VIII. WSRT Ranks

Test Statistics NFB[c]

	Signal Detection Retest - Signal Detection	Spatial Orientation Retest - Spatial Orientation	Reaction Time Retest - Reaction Time	Motor Time Retest - Motor Time	Dispersion Reaction Time Retest - Dispersion Reaction Time	Dispersion Motor Time Retest - Dispersion Motor Time	Corsi Block-Tapping Retest - Corsi Block-Tapping Test	Reading Interference Retest - Reading Interference	Naming Interference Retest - Naming Interference	Stroop Retest Time - Stroop Test Time	Pace Auditory Addition Re-task - Pace Auditory Addition Task
Z	-1,095[a]	-2,032[b]	-2,032[b]	-2,032[b]	-1,826[b]	-1,095[b]	-1,732[b]	-1,461[b]	-1,633[b]	-,944[a]	-1,084[b]
Asymp. Sig. (2-tailed)	,273	,042	,042	,042	,068	,273	,083	,144	,102	,345	,279

a. Based on positive ranks.

b. Based on negative ranks.

c. Wilcoxon Signed Ranks Test

Table IX. WSRT statistics

Descriptive Statistics

	N	Mean
Spatial Orientation	5	51,00
Spatial Orientation Retest	5	61,00
Reaction Time	5	65,80
Reaction Time Retest	5	70,20
Motor Time	5	61,20
Motor Time Retest	5	67,40
Valid N (listwise)	5	

Table X. WSRT pre and post training means

3.1.2.b Meditation

In the case of MED group, the comparison of pre and post training performance brought more variable results. The observed differences don’t follow the improvement trend which is possible to observe in NFB group for most of variables. Overall MED group performed better in some tasks at time-1 while in other tasks was performance better at time-2. There are also some ties between test and retest. In the case of MED group WSRT doesn’t affirm significant changes (at 0,05 level) in any of the tested variables, consequent to participation in meditation training program. The smallest p-value shows spatial orientation (0,055). We can conclude that at the level $\alpha = 0,05$ of significance, there is not enough evidence that participation in MED training led to enhanced performance in any of the observed tasks.

Test Statistics MED[c]

	Signal Detection Retest - Signal Detection	Spatial Orientation Retest - Spatial Orientation	Reaction Time Retest - Reaction Time	Motor Time Retest - Motor Time	Dispersion Reaction Time Retest - Dispersion Reaction Time	Dispersion Motor Time Retest - Dispersion Motor Time	Corsi Block-Tapping Retest - Corsi Block-Tapping Test	Reading Interference Retest - Reading Interference	Naming Interference Retest - Naming Interference	Stroop Retest Time - Stroop Test Time	Pace Auditory Addition Re-task - Pace Auditory Addition Task
Z	-1,000[a]	-1,604[b]	-,184[b]	-1,461[a]	-,447[b]	-,677[a]	-,577[b]	-1,095[b]	-1,214[b]	-1,084[a]	-,944[b]
Asymp. Sig. (2-tailed)	,317	,109	,854	,144	,655	,498	,564	,273	,225	,279	,345

a. Based on positive ranks.

b. Based on negative ranks.

c. Wilcoxon Signed Ranks Test

Table XI. WSRT

3.1.2.c Controls

WSRT for controls shows similar results to those of MED group. There are some differences between the two performance measurements, but there can't be estimated any obvious sequence of these differences. Once again, group performance was greater in some tasks at time-1, while other tasks group completed better at time-2; like in MED group there were some ties between the measurements. The test statistics for CNTRL group reveals no significant changes (at 0,05 level) in neither of the variables tested. The smallest p-value can be find for motor time in Reaction Test (0,11). Since all the p-values are > 0,05, we fail to reject the null hypothesis. At the level α = 0,05 of significance, there is not enough evidence to conclude that performance at time-1 was better than performance at time-2.

Test Statistics CNTRL[d]

	Signal Detection Retest - Signal Detection	Spatial Orientation Retest - Spatial Orientation	Reaction Time Retest - Reaction Time	Motor Time Retest - Motor Time	Dispersion Reaction Time Retest - Dispersion Reaction Time	Dispersion Motor Time Retest - Dispersion Motor Time	Corsi Block-Tapping Retest - Corsi Block-Tapping Test	Reading Interference Retest - Reading Interference	Naming Interference Retest - Naming Interference	Stroop Retest Time - Stroop Test Time	Pace Auditory Addition Re-task - Pace Auditory Addition Task
Z	-,552[a]	-,378[b]	-,674[b]	-1,225[a]	,000[c]	-,406[a]	-1,000[b]	-,944[b]	-,680[a]	-1,214[a]	-1,461[a]
Asymp. Sig. (2-tailed)	,581	,705	,500	,221	1,000	,684	,317	,345	,496	,225	,144

a. Based on positive ranks.

b. Based on negative ranks.

c. The sum of negative ranks equals the sum of positive ranks.

d. Wilcoxon Signed Ranks Test

Table XII. WSRT

3.2. EEG analysis

Comparison of interhemispheric coherence BMs obtained for RELAX at time-1 and time-2, BMs represent 20 second sequences.

From the BEAMs we may observe global trend towards higher intehemispheric coherence at time-2. Using spectral analysis, the global numeric values for nine coherence pairs were computed (in Hz). The difference values between coherence at time-2 and time-1 were calculated for each of coherence pairs.

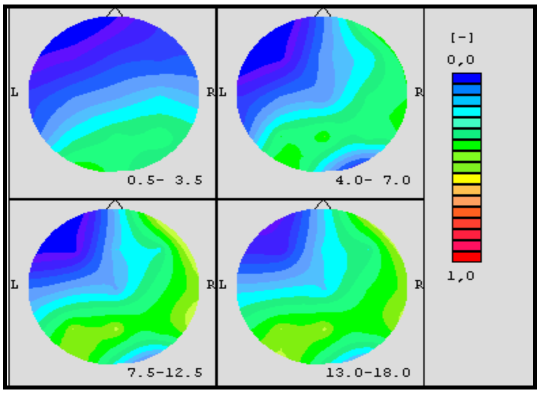
Case Summaries[a]

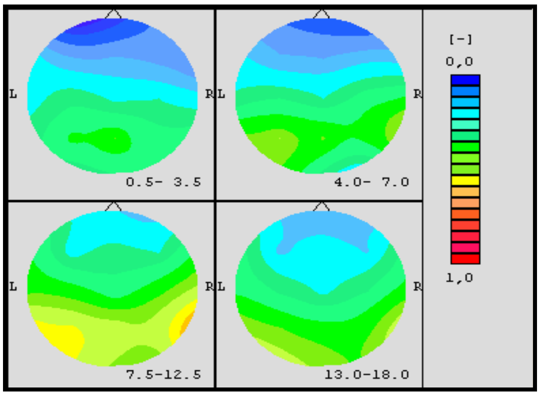
	Experimental Group												
	NFB						MED						Total
	1	2	3	4	5	Total N	1	2	3	4	5	Total N	N
Coherence Fp1-F3	1,54	1,91	,71	,56	,69	5	1,64	,12	2,86	,51	,17	5	10
Coherence Fp2-F4	1,60	1,84	,74	,60	,63	5	2,07	,14	2,66	,32	,84	5	10
Coherence F3-C3	1,86	2,42	1,72	1,40	1,22	5	2,37	,29	2,93	1,19	,63	5	10
Coherence F4-C4	1,94	2,17	1,30	,85	2,28	5	1,73	,47	2,65	,78	1,61	5	10
Coherence C3-P3	3,01	3,00	2,38	1,89	1,07	5	3,07	1,59	3,26	1,88	2,34	5	10
Coherence C4-P4	2,77	2,89	2,24	1,75	2,04	5	2,07	2,08	3,18	1,44	2,64	5	10
Coherence P3-O1	2,81	3,26	3,43	2,18	2,72	5	3,39	2,02	3,12	2,84	2,34	5	10
Coherence P4-O2	2,43	3,06	2,93	2,52	2,14	5	2,87	1,06	3,30	2,46	2,70	5	10
Coherence Fp1-F3 time-2	,13	,22	,98	,55	1,75	5	1,77	,13	,59	,86	,85	5	10
Coherence Fp2-F4 time-2	2,95	,19	,39	,74	2,12	5	2,29	,28	,89	,60	,85	5	10
Coherence F3-C3 time-2	,94	,80	2,07	1,14	2,45	5	2,56	,39	,84	1,62	,85	5	10
Coherence F4-C4 time-2	2,52	1,40	1,75	1,02	2,24	5	1,01	,79	1,30	,83	1,59	5	10
Coherence C3-P3 time-2	3,79	2,39	3,61	2,67	3,00	5	3,19	1,84	2,23	1,95	1,24	5	10
Coherence C4-P4 time-2	4,66	1,81	2,83	2,68	3,21	5	2,18	1,91	2,67	1,60	2,70	5	10
Coherence P3-O1 time-2	4,24	2,96	3,11	2,73	3,25	5	1,60	2,23	2,45	2,95	3,13	5	10
Coherence P4-O2 time-2	2,29	2,81	3,64	2,88	3,24	5	2,11	1,07	2,83	2,45	3,08	5	10
D_Fp1_F3	-1,41	-1,69	,27	-,01	1,06	5	,13	,00	-2,27	,35	,68	5	10
D_Fp2_F4	1,35	-1,65	-,35	,14	1,49	5	,22	,14	-1,77	,28	,01	5	10
D_F3_C3	-,92	-1,62	,35	-,26	1,23	5	,19	,10	-2,09	,43	,22	5	10
D_F4_C4	,58	-,77	,45	,17	-,04	5	-,72	,32	-1,35	,05	-,02	5	10
D_C3_P3	,78	-,61	1,23	,78	1,93	5	,12	,25	-1,03	,07	-1,10	5	10
D_C4_P4	1,89	-1,08	,59	,93	1,17	5	,11	-,17	-,51	,16	,06	5	10
D_P3_O1	1,43	-,30	-,32	,55	,53	5	-1,79	,21	-,67	,11	,79	5	10
D_P4_O2	-,14	-,25	,71	,36	1,10	5	-,76	,00	-,47	-,01	,38	5	10

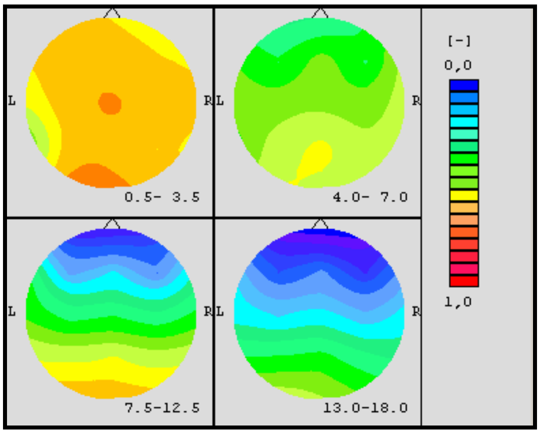
a. Limited to first 100 cases.

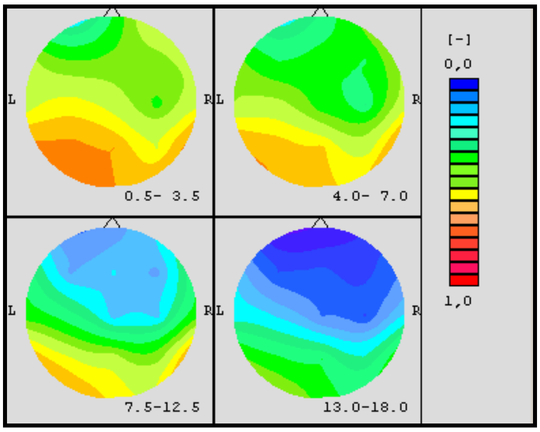
Table XIII. Coherence values (in Hz) time-1, time-2, difference

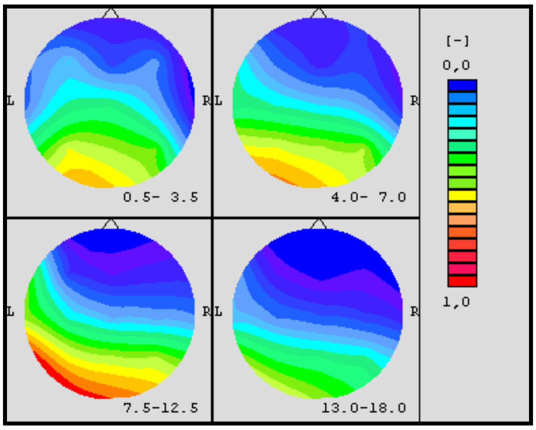
3.2.a Neurofeedback Group

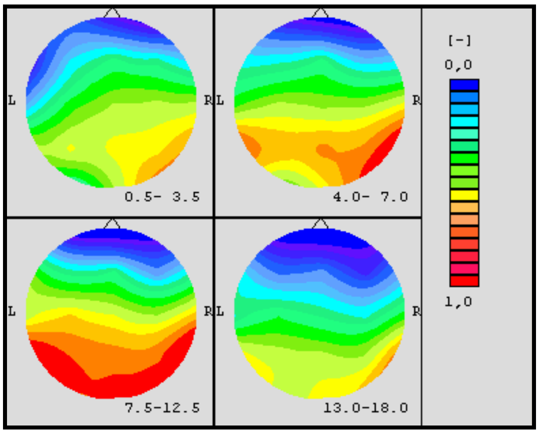


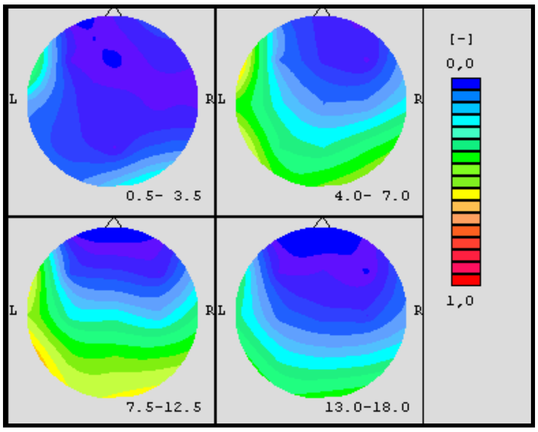


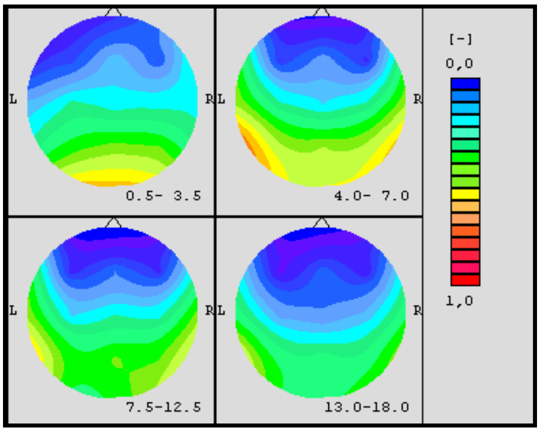


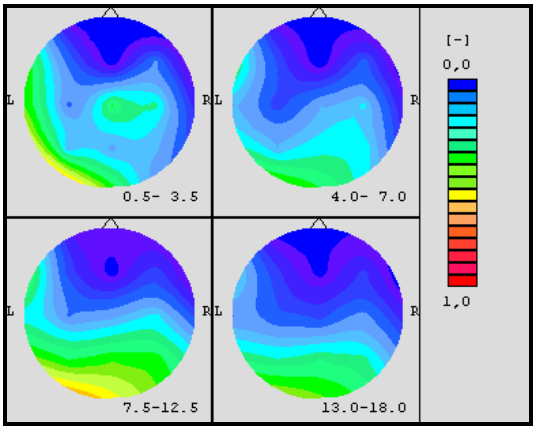


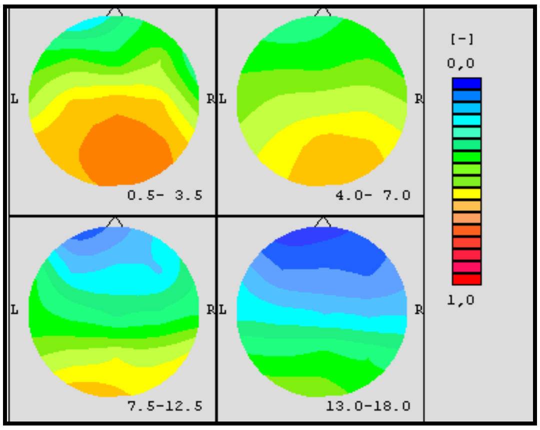




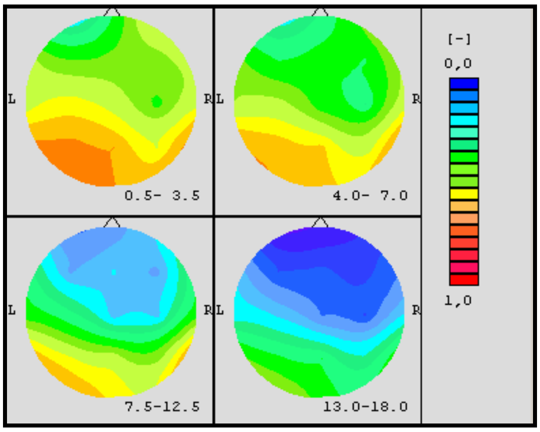


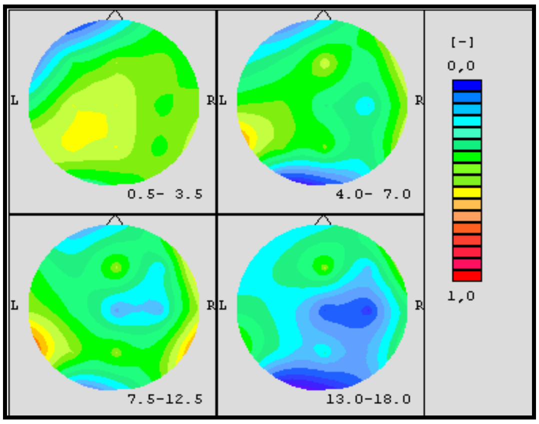


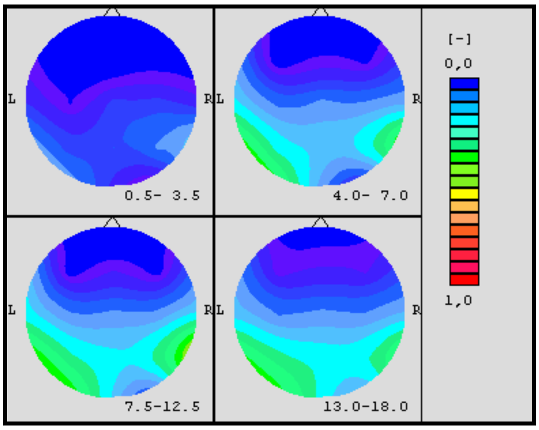


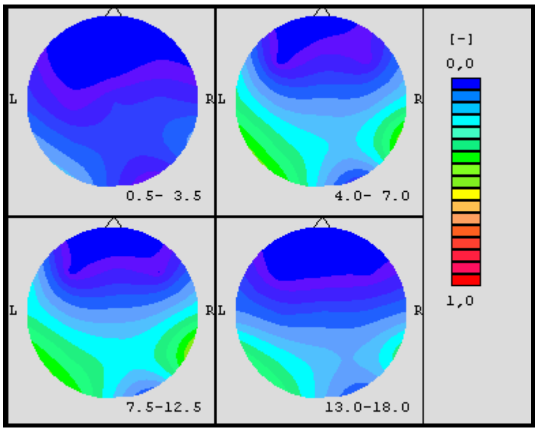


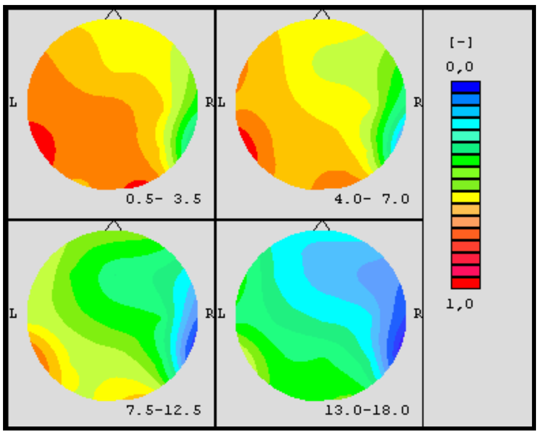
3.2.b Meditation Group

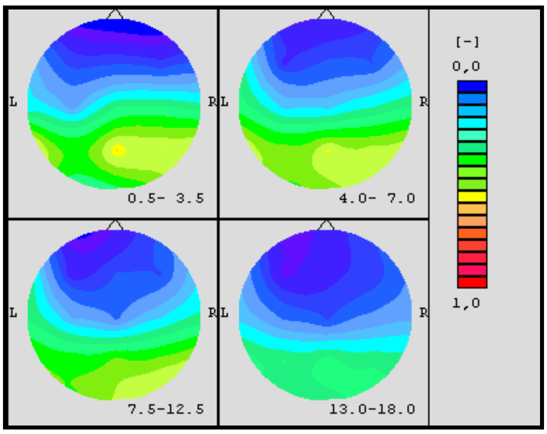


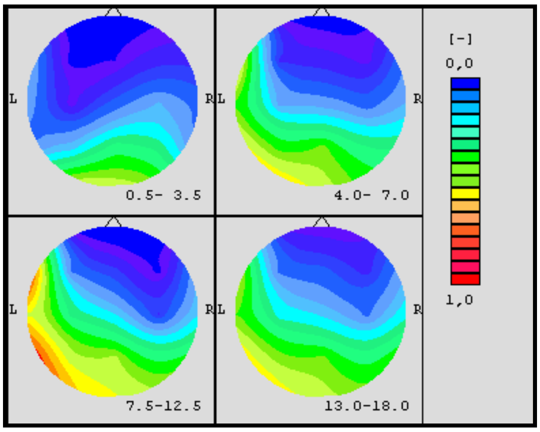


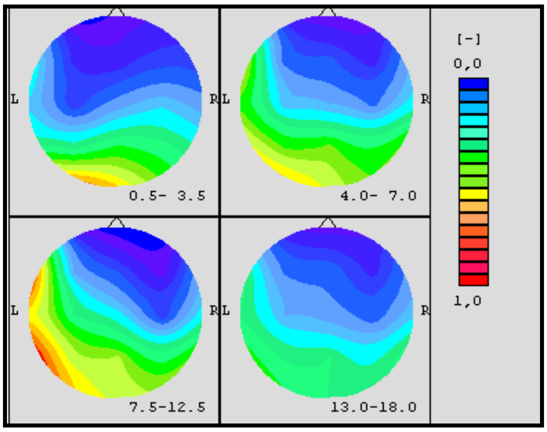


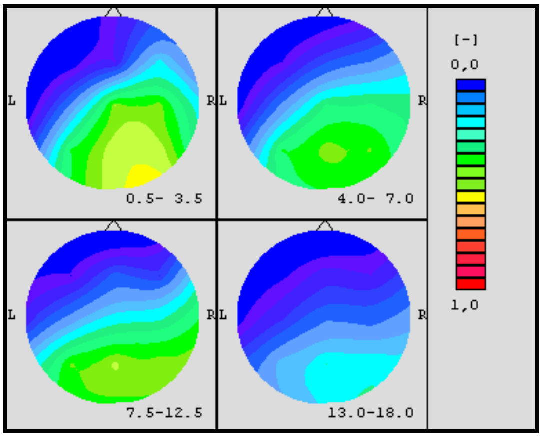


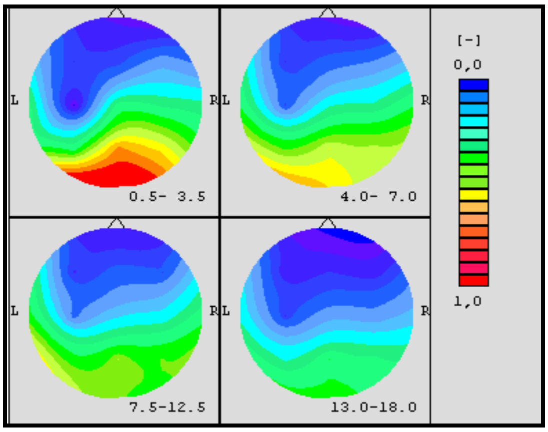












3.3. Test Results x Coherence Correlation

Pearson correlation revealed significant relationship between results in some cognitive tasks and some coherence pairs at both time-1 and time-2. However, overall correlation between test results and coherence pairs is mainly not significant.

$$H0 : \rho = 0$$
$$Ha : \rho \neq 0$$

3.3.1. Time-1 Correlations

A correlation for the data at time-1 revealed that the result in Signal Detection task and coherence for pairs P3-01 are significantly related, $r = +{,}680$, $n = 10$, $p < 0{,}05$. There is also significant relationship between coherence pair P3-01 and reaction time in Reaction Test, $r = +{,}648$, $p < 0{,}05$. Significantly negative relationship exists between reading interference in STROOP test and coherence pair Fp2-F4, $r = -{,}659$, $p < 0{,}05$, and between reading interference and coherence pair F4-C4, $r = -{,}867$, $p < 0{,}01$ (see Table XIV.).

3.3.2. Time-2 Correlations

A correlation for the data at time-2 revealed strong negative relationship between results in Spatial Orientation task and coherence pair Fp2-F4, $r = -{,}803$, $n = 10$, $p<0{,}01$, and between Spatial Orientation and coherence pair F4-C4, $r = -{,}644$, $p<0{,}05$. There is also significant negative relation between Spatial Orientation and coherence pair C4-P4, $r = -{,}702$, $p<0{,}05$.

Data also revealed relationship between reaction time in Reaction Test and coherence pair C3-P3, $r = ,634$, $p<0,05$. Negative relation exists between reading interference in STROOP task and coherence pair F4-C4, $r = -,699$, $p<0,05$, and between reading interference and coherence pair P3-O1, $r = -,707$, $p<0,05$. There is strong relationship between STROOP time and coherence pair Fp2-F4, $r = ,899$, $p<0,01$, and relation between STROOP time and coherence pair C4-P4, $r = ,644$, $p<0,05$ (see Table XV.).

Correlations

		Signal Detection	Spatial Orientation	Reaction Time	Motor Time	Dispersion Reaction Time	Dispersion Motor Time	Corsi Block-Tapping Test	Reading Interference	Naming Interference	Stroop Test Time	Pace Auditory Addition Task	Coherence Fp1-F3	Coherence Fp2-F4	Coherence F3-C3	Coherence F4-C4	Coherence C3-P3	Coherence C4-P4	Coherence P3-O1	Coherence P4-O2
Signal Detection	Pearson Correlation	1	,276	-,669*	-,047	-,190	,034	,346	-,079	,002	,076	,112	-,155	-,114	-,395	,051	-,378	,090	-,680*	-,448
	Sig. (2-tailed)		,440	,034	,898	,598	,926	,327	,828	,996	,834	,758	,669	,754	,259	,888	,282	,805	,030	,194
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Spatial Orientation	Pearson Correlation	,276	1	-,002	,636*	,287	,448	,096	,673*	-,614	-,661*	,267	-,269	-,278	-,246	-,559	-,288	-,458	-,337	-,276
	Sig. (2-tailed)	,440		,996	,048	,422	,194	,793	,033	,059	,038	,456	,452	,436	,493	,093	,420	,183	,342	,441
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Reaction Time	Pearson Correlation	-,669*	-,002	1	,320	,694*	,043	-,264	,253	-,440	-,311	,048	,211	,154	,315	-,037	,260	-,045	,648*	,031
	Sig. (2-tailed)	,034	,996		,368	,026	,906	,461	,481	,203	,382	,894	,559	,671	,376	,919	,468	,902	,043	,932
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Motor Time	Pearson Correlation	-,047	,636*	,320	1	,236	,805**	,274	,316	-,796**	-,243	-,248	-,176	-,078	-,050	-,181	-,144	-,426	,177	,030
	Sig. (2-tailed)	,898	,048	,368		,511	,005	,443	,374	,006	,498	,490	,627	,831	,890	,617	,691	,220	,625	,934
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Dispersion Reaction Time	Pearson Correlation	-,190	,287	,694*	,236	1	-,120	-,160	,237	-,501	-,397	,281	,112	,018	,171	-,178	-,044	-,238	,337	-,238
	Sig. (2-tailed)	,598	,422	,026	,511		,742	,659	,509	,140	,256	,432	,757	,960	,638	,622	,904	,508	,340	,509
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Dispersion Motor Time	Pearson Correlation	,034	,448	,043	,805**	-,120	1	,146	,410	-,659*	,046	-,277	-,586	-,399	-,471	-,383	-,334	-,492	-,200	-,203
	Sig. (2-tailed)	,926	,194	,906	,005	,742		,686	,239	,038	,900	,439	,075	,253	,169	,274	,345	,148	,579	,574
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Corsi Block-Tapping Test	Pearson Correlation	,346	,096	-,264	,274	-,160	,146	1	-,436	-,390	,428	-,030	,380	,585	,313	,403	,508	,405	,191	,453
	Sig. (2-tailed)	,327	,793	,461	,443	,659	,686		,208	,266	,217	,935	,279	,075	,379	,248	,134	,245	,597	,188
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Reading Interference	Pearson Correlation	-,079	,673*	,253	,316	,237	,410	-,436	1	-,418	-,697*	,504	-,619	-,659*	-,589	-,867**	-,400	-,504	-,432	-,575
	Sig. (2-tailed)	,828	,033	,481	,374	,509	,239	,208		,229	,025	,137	,056	,038	,073	,001	,252	,138	,213	,082
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Naming Interference	Pearson Correlation	,002	-,614	-,440	-,796**	-,501	-,659*	-,390	-,418	1	,149	-,104	,157	,000	,092	,314	-,062	,257	-,113	,146
	Sig. (2-tailed)	,996	,059	,203	,006	,140	,038	,266	,229		,682	,774	,666	1,000	,800	,377	,865	,474	,757	,687
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Stroop Test Time	Pearson Correlation	,076	-,661*	-,311	-,243	-,397	,046	,428	-,697*	,149	1	-,473	,118	,314	,102	,428	,290	,263	,078	,229
	Sig. (2-tailed)	,834	,038	,382	,498	,256	,900	,217	,025	,682		,168	,746	,377	,779	,217	,417	,463	,831	,524
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Pace Auditory Addition Task	Pearson Correlation	,112	,267	,048	-,248	,281	-,277	-,030	,504	-,104	-,473	1	-,232	-,292	-,328	-,482	-,057	,024	-,221	-,303
	Sig. (2-tailed)	,758	,456	,894	,490	,432	,439	,935	,137	,774	,168		,519	,413	,356	,158	,877	,947	,540	,395
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence Fp1-F3	Pearson Correlation	-,155	-,269	,211	-,176	,112	-,586	,380	-,619	,157	,118	-,232	1	,951**	,943**	,764*	,788**	,680*	,640*	,658*
	Sig. (2-tailed)	,669	,452	,559	,627	,757	,075	,279	,056	,666	,746	,519		,000	,000	,010	,007	,030	,046	,039
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence Fp2-F4	Pearson Correlation	-,114	-,278	,154	-,078	,018	-,399	,585	-,659*	,000	,314	-,292	,951**	1	,901**	,785**	,873**	,735*	,624	,706*
	Sig. (2-tailed)	,754	,436	,671	,831	,960	,253	,075	,038	1,000	,377	,413	,000		,000	,007	,001	,015	,054	,022
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence F3-C3	Pearson Correlation	-,395	-,246	,315	-,050	,171	-,471	,313	-,589	,092	,102	-,328	,943**	,901**	1	,698*	,779**	,522	,789**	,795**
	Sig. (2-tailed)	,259	,493	,376	,890	,638	,169	,379	,073	,800	,779	,356	,000	,000		,025	,008	,122	,007	,006
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence F4-C4	Pearson Correlation	,051	-,559	-,037	-,181	-,178	-,383	,403	-,867**	,314	,428	-,482	,764*	,785**	,698*	1	,497	,741*	,539	,613
	Sig. (2-tailed)	,888	,093	,919	,617	,622	,274	,248	,001	,377	,217	,158	,010	,007	,025		,144	,014	,108	,059
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence C3-P3	Pearson Correlation	-,378	-,288	,260	-,144	-,044	-,334	,508	-,400	-,062	,290	-,057	,788**	,873**	,779**	,497	1	,689*	,605	,700*
	Sig. (2-tailed)	,282	,420	,468	,691	,904	,345	,134	,252	,865	,417	,877	,007	,001	,008	,144		,028	,064	,024
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence C4-P4	Pearson Correlation	,090	-,458	-,045	-,426	-,238	-,492	,405	-,504	,257	,263	,024	,680*	,735*	,522	,741*	,689*	1	,295	,454
	Sig. (2-tailed)	,805	,183	,902	,220	,508	,148	,245	,138	,474	,463	,947	,030	,015	,122	,014	,028		,409	,188
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence P3-O1	Pearson Correlation	-,680*	-,337	,648*	,177	,337	-,200	,191	-,432	-,113	,078	-,221	,640*	,624	,789**	,539	,605	,295	1	,724*
	Sig. (2-tailed)	,030	,342	,043	,625	,340	,579	,597	,213	,757	,831	,540	,046	,054	,007	,108	,064	,409		,018
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence P4-O2	Pearson Correlation	-,448	-,276	,031	,030	-,238	-,203	,453	-,575	,146	,229	-,303	,658*	,706*	,795**	,613	,700*	,454	,724*	1
	Sig. (2-tailed)	,194	,441	,932	,934	,509	,574	,188	,082	,687	,524	,395	,039	,022	,006	,059	,024	,188	,018	
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table XIV. Correlations between coherence pairs and test results at time-1

Correlations

		Signal Detection Retest	Spatial Orientation Retest	Reaction Time Retest	Motor Time Retest	Dispersion Reaction Time Retest	Dispersion Motor Time Retest	Corsi Block-Tapping Retest	Reading Interference Retest	Naming Interference Retest	Stroop Retest Time	Pace Auditory Addition Re-task	Coherence Fp1-F3 time-2	Coherence Fp2-F4 time-2	Coherence F3-C3 time-2	Coherence F4-C4 time-2	Coherence C3-P3 time-2	Coherence C4-P4 time-2	Coherence P3-O1 time-2	Coherence P4-O2 time-2
Signal Detection Retest	Pearson Correlation	1	-,033	-,514	-,479	-,170	,051	-,047	,072	,133	-,102	,329	-,062	-,098	-,348	,059	-,540	,081	,033	-,133
	Sig. (2-tailed)		,927	,129	,161	,639	,889	,897	,844	,715	,779	,354	,865	,787	,324	,872	,107	,824	,929	,714
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Spatial Orientation Retest	Pearson Correlation	-,033	1	,185	,504	,166	,624	,468	,662*	-,221	-,759*	,134	,005	-,803**	-,044	-,644*	-,325	-,702*	-,585	,045
	Sig. (2-tailed)	,927		,609	,137	,647	,054	,172	,037	,540	,011	,712	,990	,005	,904	,044	,360	,024	,076	,902
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Reaction Time Retest	Pearson Correlation	-,514	,185	1	,360	,788**	,100	,181	,132	,151	-,281	-,105	,111	,008	,400	,093	,634*	-,080	-,095	-,067
	Sig. (2-tailed)	,129	,609		,308	,007	,784	,616	,716	,677	,432	,773	,760	,982	,252	,798	,049	,827	,793	,855
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Motor Time Retest	Pearson Correlation	-,479	,504	,360	1	,162	,627	,022	-,023	-,603	-,118	-,284	,333	-,286	,326	-,167	-,047	-,505	-,312	,264
	Sig. (2-tailed)	,161	,137	,308		,654	,052	,951	,950	,065	,746	,427	,347	,423	,358	,645	,898	,136	,380	,461
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Dispersion Reaction Time Retest	Pearson Correlation	-,170	,166	,788**	,162	1	-,053	,553	,347	,228	-,274	,015	,119	,046	,268	,012	,494	-,089	-,325	-,153
	Sig. (2-tailed)	,639	,647	,007	,654		,884	,097	,325	,526	,443	,968	,743	,900	,454	,975	,146	,807	,359	,673
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Dispersion Motor Time Retest	Pearson Correlation	,051	,624	,100	,627	-,053	1	-,126	-,073	-,336	-,273	-,312	,584	-,356	,493	-,072	-,139	-,345	-,206	,540
	Sig. (2-tailed)	,889	,054	,784	,052	,884		,729	,841	,343	,446	,380	,076	,312	,148	,844	,702	,328	,568	,107
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Corsi Block-Tapping Retest	Pearson Correlation	-,047	,468	,181	,022	,553	-,126	1	,835**	,147	-,378	,425	-,179	-,383	-,200	-,433	,005	-,304	-,596	-,072
	Sig. (2-tailed)	,897	,172	,616	,951	,097	,729		,003	,684	,282	,221	,620	,275	,581	,211	,990	,393	,069	,844
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Reading Interference Retest	Pearson Correlation	,072	,662*	,132	-,023	,347	-,073	,835**	1	-,034	-,577	,493	-,309	-,561	-,364	-,699*	-,242	-,492	-,707*	-,410
	Sig. (2-tailed)	,844	,037	,716	,950	,325	,841	,003		,926	,081	,148	,384	,091	,302	,025	,500	,149	,022	,239
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Naming Interference Retest	Pearson Correlation	,133	-,221	,151	-,603	,228	-,336	,147	-,034	1	-,247	,289	-,437	-,040	-,217	,391	,381	,470	,568	,236
	Sig. (2-tailed)	,715	,540	,677	,065	,526	,343	,684	,926		,491	,418	,206	,913	,548	,264	,277	,171	,087	,511
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Stroop Retest Time	Pearson Correlation	-,102	-,759*	-,281	-,118	-,274	-,273	-,378	-,577	-,247	1	-,458	,304	,861**	,242	,597	,325	,664*	,307	,128
	Sig. (2-tailed)	,779	,011	,432	,746	,443	,446	,282	,081	,491		,183	,394	,001	,501	,069	,359	,036	,389	,724
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Pace Auditory Addition Re-task	Pearson Correlation	,329	,134	-,105	-,284	,015	-,312	,425	,493	,289	-,458	1	-,560	-,587	-,628	-,306	-,496	-,316	-,080	-,179
	Sig. (2-tailed)	,354	,712	,773	,427	,968	,380	,221	,148	,418	,183		,092	,074	,052	,390	,145	,374	,825	,621
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence Fp1-F3 time-2	Pearson Correlation	-,062	,005	,111	,333	,119	,584	-,179	-,309	-,437	,304	-,560	1	,372	,913**	,076	,210	-,070	-,327	,347
	Sig. (2-tailed)	,865	,990	,760	,347	,743	,076	,620	,384	,206	,394	,092		,290	,000	,835	,561	,847	,356	,325
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence Fp2-F4 time-2	Pearson Correlation	-,098	-,803**	,008	-,286	,046	-,356	-,383	-,561	-,040	,861**	-,587	,372	1	,416	,608	,584	,718*	,284	-,062
	Sig. (2-tailed)	,787	,005	,982	,423	,900	,312	,275	,091	,913	,001	,074	,290		,231	,062	,076	,019	,426	,865
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence F3-C3 time-2	Pearson Correlation	-,348	-,044	,400	,326	,268	,493	-,200	-,364	-,217	,242	-,628	,913**	,416	1	,175	,523	,034	-,169	,384
	Sig. (2-tailed)	,324	,904	,252	,358	,454	,148	,581	,302	,548	,501	,052	,000	,231		,628	,121	,926	,641	,273
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence F4-C4 time-2	Pearson Correlation	,059	-,644*	,093	-,167	,012	-,072	-,433	-,699*	,391	,597	-,306	,076	,608	,175	1	,553	,866**	,794**	,453
	Sig. (2-tailed)	,872	,044	,798	,645	,975	,844	,211	,025	,264	,069	,390	,835	,062	,628		,097	,001	,006	,188
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence C3-P3 time-2	Pearson Correlation	-,540	-,325	,634*	-,047	,494	-,139	,005	-,242	,381	,325	-,496	,210	,584	,523	,553	1	,599	,290	,220
	Sig. (2-tailed)	,107	,360	,049	,898	,146	,702	,990	,500	,277	,359	,145	,561	,076	,121	,097		,067	,417	,542
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence C4-P4 time-2	Pearson Correlation	,081	-,702*	-,080	-,505	-,089	-,345	-,304	-,492	,470	,664*	-,316	-,070	,718*	,034	,866**	,599	1	,710*	,233
	Sig. (2-tailed)	,824	,024	,827	,136	,807	,328	,393	,149	,171	,036	,374	,847	,019	,926	,001	,067		,021	,518
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence P3-O1 time-2	Pearson Correlation	,033	-,585	-,095	-,312	-,325	-,206	-,596	-,707*	,568	,307	-,080	-,327	,284	-,169	,794**	,290	,710*	1	,372
	Sig. (2-tailed)	,929	,076	,793	,380	,359	,568	,069	,022	,087	,389	,825	,356	,426	,641	,006	,417	,021		,289
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Coherence P4-O2 time-2	Pearson Correlation	-,133	,045	-,067	,264	-,153	,540	-,072	-,410	,236	,128	-,179	,347	-,062	,384	,453	,220	,233	,372	1
	Sig. (2-tailed)	,714	,902	,855	,461	,673	,107	,844	,239	,511	,724	,621	,325	,865	,273	,188	,542	,518	,289	
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table XV. Correlations between coherence pairs and test results at time-2

4. Discussion

One of the main purposes of this study was to determine if short-term neurofeedback and meditation training have effect on cognitive performance, and if there is any relationship between cognitive performance and coherence during relaxation, in the sites that correspond to cortical activation during specific task solving. The results obtained in comparison of pre and post training performance by Wilcoxon Signed Rank Test suggest, in accordance with previous research (Vernon et al., 2003; Hanslmyar et al., 2005), that short-term neurofeedback training improves cognitive performance. There were found significant differences in spatial orientation, reaction time and motor response. The findings support previous finding that theta oscillations are related to sensorimotor integration and spatial learning (Caplan et al., 2003). Also reaction time and motor response were previously found to be related to sensorimotor rhythm (Mates et al., 1994; Leocani et al., 2001). The results are consistent with findings associating SMR enhancement and increased perceptual sensitivity 'd prime' (Egner & Gruzelier, 2004). However, there was found no evidence that increased SMR leads to higher attention performance, possibly for the fact that beta frequency increase was not included in the training protocol. There were some observable trends suggesting improved performance in some other cognitive tasks. Namely Corsi Block-Tapping Test showed significant improvement which wasn't supported for ties (n = 3). Still, the result is interesting as CORSI test measures visuo-spatial memory span.

For the meditation group, as for the control group, there were found no significant differences in cognitive performance at the two measurements. While NFB group showed general trend towards performance improvement, MED and CNTRL groups had more various results and there were many ties which disallowed to draw any conclusions.

EEG analysis of pre and post relaxation state revealed general trend towards greater general interhemispheric coherence in anterior-posterior direction for site pairs Fp1-F3, Fp2-F4, F3-C3, F4-C4, C3-P3, C4-P4, P3-O1, P4-O2. This trend was visible especially in posterior areas which are related to preattentive processes. When compared to concentrative meditation, relaxation shows lower coherence levels (Dunn et al., 1999). From the maps for individual frequency bands it is difficult to come to any conclusion, as there isn't possible to observe any general pattern for neither of the groups (MED, NFB). There is rather small alpha activity in frontal areas, which was suggested to be important factor of relaxation related to emotional arousal (Austin, 1999) and there are also no traces of synchronic alpha pattern over the whole cerebral surface as indicated in some other studies (Smith, 1999). Greater coherence at time-2 could be also caused by different conditions during EEG recording at time-1 and time-2 or accidental mental activity. There is some difference between groups as to delta coherence, which typically occurs during transition from wakefulness to sleep, and which shows greater coherence in time-2 for the NFB group. This would support the claims of neurofeedback participants that they felt tired during the training period. Most notable is the difference in theta coherence in pre post measurements for NFB group. The pattern towards greater coherence is followed by all the subjects and is most obvious in parietal areas. This trend supports hypothesis of double dissociation (Klimesch, 1999) that relates higher theta power in rest with increased cognitive performance.

The correlation between coherence pairs and cognitive performance brought somewhat uncertain results. At time-1 there was significant relationship between performance in Signal Detection test and coherence pair P3-O1. Aim of SIGNAL task is visual detection of relevant signal in two-dimensional space. Parietal areas integrate sensory information from different modalities and are particularly related to spatial sense and navigation (Kolb & Whishaw, 2003). However, results in other tasks that should be correlated with parietal areas do not show significant relationship. This could be due to the fact that coherence between occipital and parietal areas is also related to visual processing and that there are parietal mechanisms for directed visual attention (Lynch et al., 1977), which correlated with results in SIGNAL test. Correlations between reaction time and coherence pair P3-01 (time-1), and reaction time and C3-P3 (time-2) support evidence that parietal areas are associated with promptness of reaction (Honey et al., 2000). Repeatedly in both measures, there were also found correlations between STROOP task (and reading interference) and coherence pairs Fp2-F4 and F4-C4. At time-1 were the correlations negative, while at time-2 positive relation was found. These findings support evidence of hemispheric variations for STROOP task (Yves, 1990); however, it is hard to explain the dissimilarities between the two measures as they could have been caused by many factors.

The NFB group showed evidence of neurofeedback learning during the training, as indexed by increased ration of SMR/theta over time, in consistence with previous research (Vernon, 2003). In contrast there were no instruments to control the MED group except self-contemplation of the allocated respondents. All respondents in the MED group confirmed some positive effects of the training, mainly there were mentioned improvements in sleep quality and decrease in lassitude. This testimony, however, could be caused by other factors, especially daily regimen in the rehabilitation centre and stress-free environment. On the contrary to MED group, NFB participants agreed that they were more tired during the days and some of them affirmed eye-strain. No other adverse effects were reported. When we take into account the demanding character of their training program, neurofeedback could be the cause. The controls affirmed, in concordance with MED group, that they were rather relaxed in the centre. Still, these self-observed differences could be caused by various rehabilitation programmes in the centre or some other factors.

As to the participants, there were several problems in the study design. First is the question of selection. According to Bless & Higson-Smith (2000) is haphazard sampling the most rudimentary in social sciences. Our choice of availability sampling was enforced due to training intensity and the location of rehabilitation centre. Subjects present daily in the centre was logical choice in order to prevent otherwise very likely drop-out. Thanks to this factor, during all the study there was no drop-out and none of the participants had intention to finish before all the planned procedures. All the subjects signed informed written consent, which had previously been used as a recruiting leaflet, confirming that they were suitable to undergo the investigation. The leaflet gave them also some information about the experimental schedule and techniques used, bus was slightly misleading about the purpose. Questionable is the sample representativeness. Due to factors mentioned above, there were minimal criterions to be met in order to be included in the study. Crucial were current health condition, medication, substance abuse, personal health history and family health anamnesis. However, some other characteristics that could interfere with study results were perceived secondary. They are age, sex, education, left-handedness and smoking/non-smoking. All these characteristics could act as unknown variables. As for the sex, the differences concerning the brain differences are well known, as well as dissimilarities in some cognitive abilities (e.g. Halpern, 2000). In several studies has also been demonstrated that smoking has some impact on cognitive performance in specific tasks (Ernst et al., 2001), and the same effects could have left-handedness and education. We tried to avoid these problems by using semi-randomisation (based on sex and smoking) and making experimental groups as homogenous as possible. However, as there were also many other variables that couldn't be controlled (actual situation when tested, environmental factors, weather, sun eruptions), we decided to disregard them.

Next problem of the sampling is significance testing. Random sampling is assumed for inferential statistics. The participants were allocated on preset conditions discussed above; nevertheless, the groups fail to meet the condition of independence, as they were being recruited together. For most tests is independence the basic assumption for possible results inference.

The most problematic part though, is the total number of participants, which is very low. Small sample bias is one of the major problems statistics deal with, as there are simply situations that demand conclusions based on small numbers of participant, such as new medicaments testing. Small samples postulate some limitations in the use of statistical methods, especially substitution of parametric test with their non-parametric versions.

In our study we used non-parametric versions of paired-samples t-test (Wilcoxon Signed Rank Test) and one-way ANOVA (Kruskal-Wallis ANOVA), because of the small sample size and hence impossibility to estimate normal distribution. Although all the test assumptions were usually met, there were some problems, especially when estimating data symmetry for WSRT. The premises were fulfilled quite roughly as it is hard to estimate symmetry on $n = 5$. Another problem connected to sample size was related to possible ties in WSRT. Fortunately, for the variables that showed significant change between the measures there were no ties, except for Corsi Block-Tapping Test. Still, the results are quite consistent and if it isn't possible to make any conclusion, there is at least possible to observe some trends which could help to aim further research. Even though there were met conditions of significance size numbers for the statistics conducted, in the case of WSRT size number was the minimal possible (n = 5). It should be therefore stated that the number of subjects was not large enough and even though they met postulates of statistical significance, the risk of Type I error is great.

As to the EEG analysis, the concept has some flaws that should be mentioned. Firstly, we correlate global coherence, which predicative degree is very low. Instead of global coherence, spectral analysis obtained values would be much more sensible choice. Coherence for individual bands would give greater answers. Secondly, even better choice than EEG coherence would be amplitude power, which is better explored and has more extensive theoretical basis. Thirdly, the concept itself is quite problematic. Even though founded on empirical evidence, there is great chance that there is hardly any relationship between EEG global coherence during relaxation and cognitive performance. There are too many possible intervening variables, starting with momentaneous mental activity during measures, which are impossible to control. Logical choice to avoid this problem would be complex time series model based on repeated measures. There is also a question to what extent is 10/20 system for 19 electrodes representative when applying on human cognitive functions, as for it’s limited spatial features.

Person correlation is based on assumption of normality which wasn’t met. This does not automatically mean statistics invalidity, but rather some serious implications connected to results interpretation. By any means, correlation is very weak statistics which does not carry too many information. For our purposes, MANOVA or rather MANCOVA methods would be most desirable when computing the relationship between different EEG sites.

5. Summary

The aim of this diploma thesis was to investigate and compare effects of meditation and neurofeedback on human neurophysiology, cognitive and attentional processes.

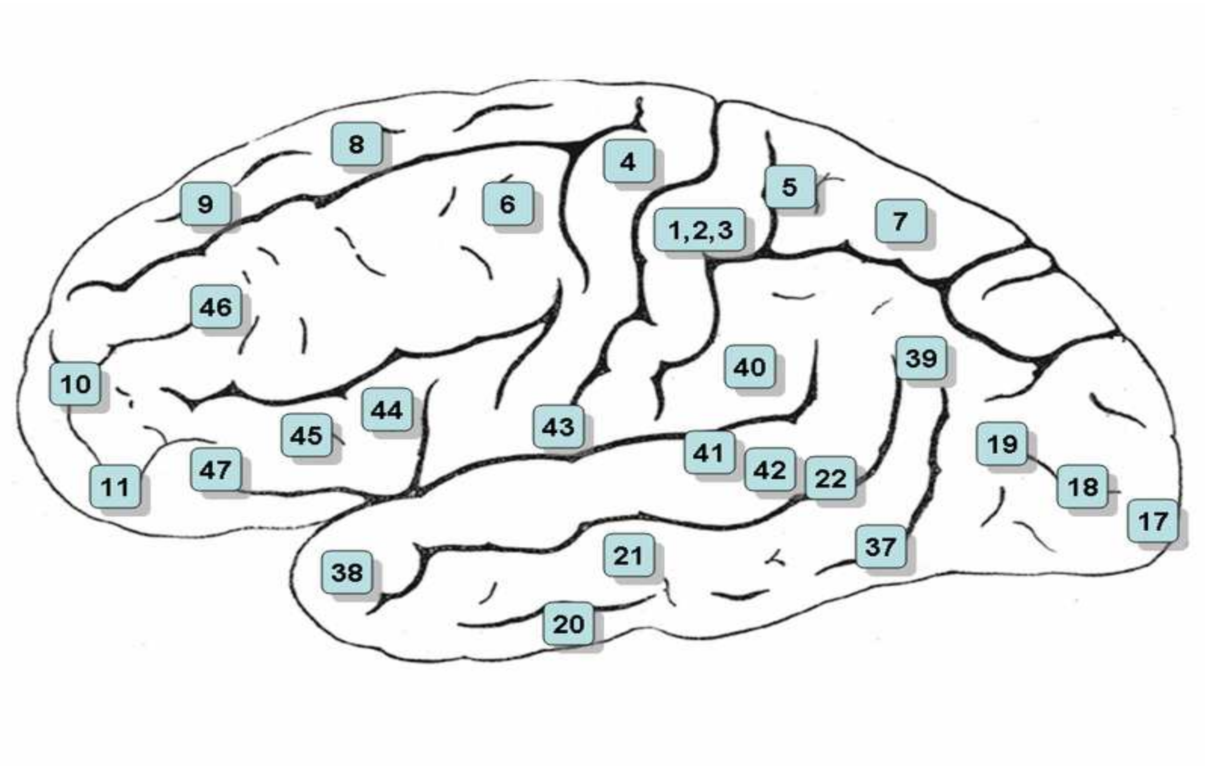
The theoretical part consists of tree chapters. First, chapter introduces the concept of meditation in neuropsychology, overviews different types of meditation, denotes methodological problems and presents health benefits and possible use in psychotherapeutic process. Second part deals with physiological specifics of meditation, meditation-induced changes in cardiovascular and cortical system, and employment of imaging methods in meditation research. Third part approaches neurofeedback from the standpoint of meditation and attempts to document some basic similarities between the two techniques and their use in psychology-related areas.

The aim of practical part is to investigate the possibility to use meditation and neurofeedback for cognitive enhancement, as previously proposed in several studies. EEG analysis was conducted in order to identify physiological patterns underlying possible effects of the two techniques on cognition. There were found some significant changes in cognitive performance induced by neurofeedback and some related EEG patterns were identified. However, due to possible Type I error the results should be viewed with caution. Overall, these preliminary findings may form background for possible further research.

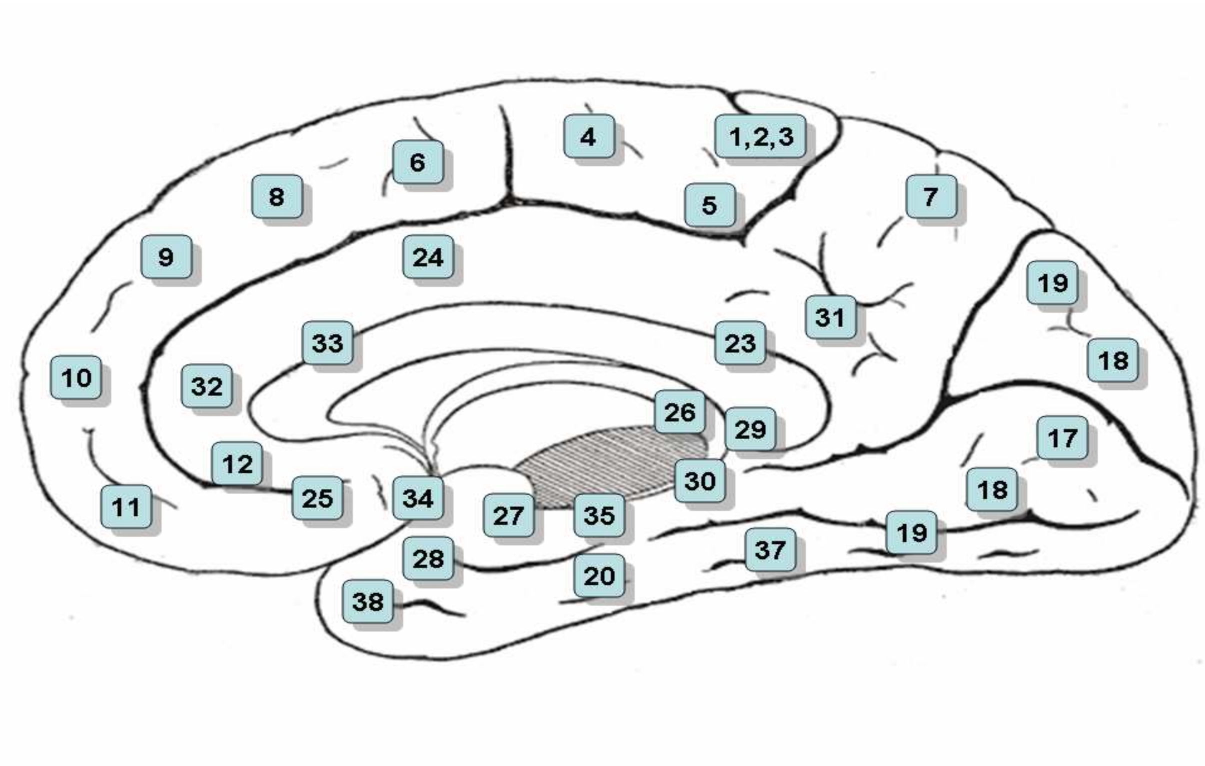
Appendices

Appendix I

Broadmann areas



Lateral surface



Medial surface

Brodmann areas for human & non-human primates

1 - intermediate postcentral (area postcentralis intermedia)
2 - caudal postcentral (area postcentralis caudalis)
3 - rostral postcentral (area postcentralis oralis)
4 - gigantopyramidal (area gigantopyramidalis)
5 - preparietal (area praeparietalis)
6 - agranular frontal (area frontalis agranularis)
7 - superior parietal (area parietalis superior)
8 - intermediate frontal (area frontalis intermedia)
9 - granular frontal (area frontalis granularis)
10 - frontopolar (area frontopolaris).
11 - prefrontal (area praefrontalis)
12 - prefrontal (area praefrontalis)
17 - striate (area striata)
18 - parastriate (area parastriata)
19 - peristriate (area peristriata)
20- inferior temporal (area temporalis inferior)
21 - middle temporal (area temporalis media)
22 - superior temporal (area temporalis superior)
23 - ventral posterior cingulate (area cingularis posterior ventralis)
24 - ventral anterior cingulate (area cingularis anterior ventralis)
25 - subgenual (area subgenualis)
26 - ectosplenial (area ectosplenialis)
28 - entorhinal (area entorhinalis)
29 - granular retrolimbic (area retrolimbica granularis)
30 - agranular retrolimbic (area retrolimbica agranularis)
31 - dorsal posterior cingulate (area cingularis posterior dorsalis)
32 - dorsal anterior cingulate (area cingularis anterior dorsalis)
33 - pregenual (area praegenualis)
34 - dorsal entorhinal (area entorhinalis dorsalis)
35 - perirhinal (area perirhinalis)
36 - ectorhinal (area ectorhinalis)
37 - occipitotemporal (area occipitotemporalis)
38 - temporopolar (area temporopolaris)
39 - angular (area angularis)
40 - supramarginal (area supramarginalis)
41 - anterior transverse temporal (area temporalis transversa anterior)
42 - posterior transverse temporal (area temporalis transversa posterior)
43 - subcentral (area subcentralis)
44 - opercular (area opercularis)
45 - triangular (area triangularis)
46 - middle frontal (area frontalis media)
47 - orbital (area orbitalis)
48 - retrosubicular (area retrosubicularis)
52 - parainsular (area parainsularis)
(13, 14, 15, 16, 27, 49, 50, 51 – only primates)

from http://en.wikipedia.org/wiki/Brodmann_area &
http://spot.colorado.edu/~dubin/talks/brodmann/neuronames.html (retreived 13th of January 2009)

Appendix II

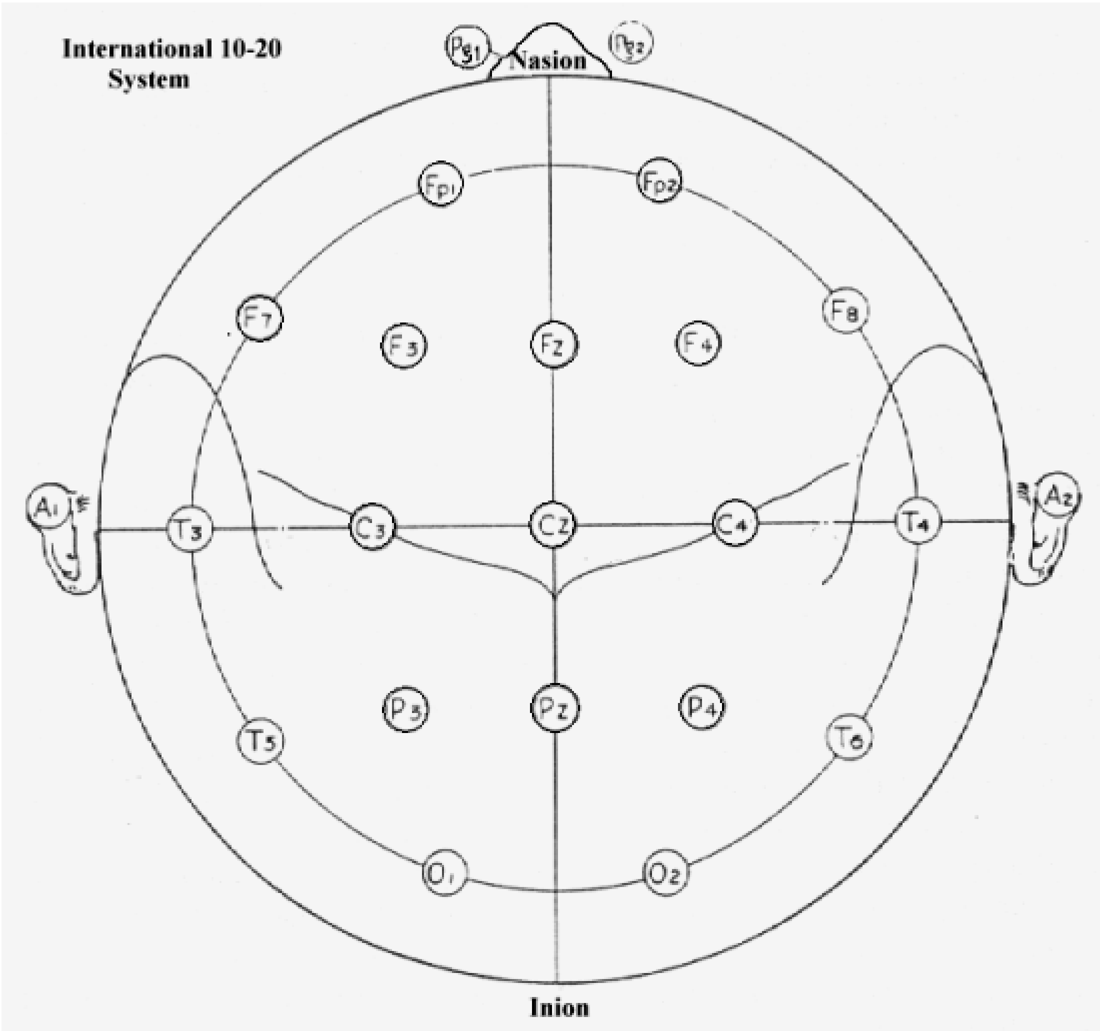


Image VII. International 10-20 system, from http://neurocog.psy.tufts.edu/images/10-20system.gif (13th of January, 2009)

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