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EEG-Guided Meditation: A Personalized Approach

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Abstract:
The therapeutic potential of meditation for physical and mental well-being is well documented, however the possibility of adverse effects warrants further discussion of the suitability of any particular meditation practice for every given participant. This concern highlights the need for a personalized approach in the meditation practice adjusted for a concrete individual. This can be done by using an objective screening procedure that detects the weak and strong cognitive skills in brain function, thus helping design a tailored meditation training protocol. Quantitative electroencephalogram (qEEG) is a suitable tool that allows identification of individual neurophysiological types. Using qEEG screening can aid developing a meditation training program that maximizes results and minimizes risk of potential negative effects. This brief theoretical-conceptual review provides a discussion of the problem and presents some illustrative results on the usage of qEEG screening for the guidance of mediation personalization.

Keywords:
Meditation; Yoga; Electroencephalogram (EEG); Mind–body practice; Physical well-being; Cognitive processes; Brain

Abbreviations:
Quantitative electroencephalogram – qEEG; Diagnostic and Statistical Manual of Mental Disorders – DSM; Orbitofrontal cortex – OFC; Positron Emission Tomography – PET; Functional Magnetic Resonance Imaging – fMRI.

1. Introduction

In the first decade of twenty-first century the abruptly increased rates of neuropsychiatric, psychosomatic and somatic disorders among the human population of industrially developed countries emerged as a result of the delay in psychophysiological adaptation to the rapidly growing technological and industrial progress. Chronic stress had been linked to the development and progression of this broad spectrum of disorders (Cohen et al., 2007).

Indeed a substantial body of experimental, clinical, and epidemiological evidence has implicated chronic stress in the etiology and progression of hypertension, cardio-vascular disorders, obesity, dyslipidemia, type2 diabetes, depression (Vitaliano et al., 2002; Cohen et al., 2007; Innes et al., 2007a,b), and related chronic conditions like sleep disturbance (Colten and Altevogt, 2006), neuroendocrine and inflammatory changes, impaired synaptic plasticity, suppression of neurogenesis and multiple neuroprotective factors; all leading to pathological alterations in mood, attention, memory, and learning (Kim and Diamond, 2002; Swaab et al., 2005; Lucassen et al., 2006, 2010; Innes et al., 2007a; Cohen et al., 2012). In their turn, these disorders have been linked to the development and progression of cognitive dysfunction, cognitive impairment, and Alzheimer's disease (Innes and Selfe, 2014).

In regard to stress, children and adolescents are of particular importance (Hagen and Nayar, 2014). The current generation of young adults has been claimed to be the most stressed-out generation (Sifferlin, 2013). For example, a 2012 online survey "Stress in America" found that millennials (18–33 years of age) are more stressed than any other current living generation (American Psychological Association, 2012). This situation is especially alarming, as pointed out by Hagen and Nayar (2014), when considering the high probability of stress habits transfer from parents to offspring (American Psychological Association, 2013).

Therapeutical approach such as meditation (an ancient mind–body practice) that specifically targets stress and related to it risk factors may hold potential for lessening the burden of chronic diseases, slowing and possibly preventing risk factors, and thus contributing to improvement of both mental and physical well-being (Bonadonna, 2003). Currently, such understanding is gaining increasing favor throughout the Western industrialized world and in the modern affective and cognitive neuroscience (Saggar et al., 2012).

2. Meditation and its effects on health

According to the Eastern spiritual tradition, meditation is a "tool" for spiritual development, where the aim is to reach an inner peace, concentration, positive emotions, while at the same time reducing stress, agitation and negative emotions (Wallace, 2005; Walsh and Shapiro, 2006). By the same token, the Western tradition uses the word “meditation” to describe a self-regulatory technique focused on maintaining one’s attention with the aim of reaching a deeply restful yet fully alert state (Mason et al., 1997; Cahn and Polich, 2006; Marciniak et al., 2014). Walsh and Shapiro (2006) suggested a merging of the two views, giving a new definition according to which meditation is a set of self-regulatory techniques focused on maintaining attention and awareness with the goal to achieve a greater rate of well-being and serenity through the enhancement of control over spiritual processes[1].

Meditation comprises a heterogeneous group of practices. One could classify them either (i) by the area of interest (Walsh and Shapiro, 2006), such as focus on a single object (sound, breath and so on) or open attention for many objects, or (ii) by the cognitive processes (Lutz et al., 2008), such as focused attention or openly monitoring attention, or (iii) by the targets (Shapiro and Walsh, 1984), such as concentration on the general mental development or on the growth of primarily specific mental qualities, such as compassion, love, or wisdom. Despite the differences in classifications there is a noticeable commonality among them, – various mediation techniques can be usefully divided on those that use focused concentration (internalized attention) and those that use open mind (mindfulness) (for a similar view see Cahn and Polich, 2006).

2.1. Positive effects of meditation

There is an increasing body of compelling evidence suggesting positive clinical outcomes of meditation for physical and psychological health. Striking examples include symptom improvements in clinical disorders, such as anxiety and depression (Farb et al., 2012; Vollestad et al., 2012), eating disorders, addictions, and disorders caused by psychoactive drugs use (Ospina et al. 2007; Balaji et al., 2012; Khanna and Greeson, 2013; Lakhan and Schofield, 2013); stress reduction, blood pressure and cholesterol levels normalization, and cardiovascular diseases prevention (Cooper and Aygen, 1978; Barnes et al., 2001; Grossman et al., 2004; Anderson et al., 2008); lowering the intensity of emotional arousal (Aftanas and Golosheykin, 2005; Nielsen and Kaszniak, 2006); enhancement of positive affect and resilience to negative affect (Davidson et al., 2003; Chambers et al., 2009; Farb et al., 2010); as well as executive functions enhancement, like attention (Brefczynski-Lewis et al., 2007; Jha et al., 2007; Pagnoni and Cekic, 2007), working memory (Newberg et al., 2010; Jha et al., 2010), verbal fluency (Alexander et al., 1989; Newberg et al., 2010), cognitive flexibility (Alexander et al., 1989; Newberg et al., 2010), introspection (Sze et al., 2010; Fox et al., 2012), and better perceptual

[1] This definition stresses active, liberated, uplifting and progressive nature of meditation, what makes it distant from other altered consciousness states such as for example hypnosis (for a discussion see Tart, 1972, 2001; see also Halsband et al., 2009 for other differences between mediation and hypnosis).

discrimination (MacLean et al., 2010); increased compassionate behavior (Condon et al., 2013); improved immune function (Davidson et al., 2003; Jacobs et al., 2011); enhanced functional and structural neuroplasticity (Cahn and Polich, 2006; Ivanovski and Malhi, 2007; Davidson and Lutz, 2008; Rubia, 2009); and even longevity (Alexander et al., 1989).

However, despite such an impressive record of positive effects, many of the reported studies are biased due to several methodological limitations like lack of subjects and control groups, and the need for blinding and randomization, as well as the frequent connections of researchers with institutions which promote a specific type of meditation. Moreover, in most studies where controls have been used, the participants were self-selected (i.e., experienced meditators) with only demographically matched controls, making it difficult to draw solid conclusions about the causal role of meditative practice for any of the reported differences. Additionally, several studies have used largely or entirely overlapping samples of meditation practitioners, adding further to the controversy.

At the same time, in spite of the mentioned methodological flaws, the multitude of reported positive effects of meditation on health made it a widely adopted mental-body exercise, that has been considered a safe and harmless practice for everyone. However, adverse (or negative) effects associated with the practice of meditation have been reported by researchers for some time, though without much attention from the public or media.

2.2. Negative effects of meditation

A number of studies have documented negative short- and long-term side-effects induced by meditation practices, such as panic attacks and anxiety (Heide and Borkovec, 1983, 1984; Cohen et al., 1985; Lazarus and Mayne, 1990); depersonalization syndrome (Kennedy, 1976; Lukoff, 1998); high blood pressure (Canter and Ernst, 2004); over-excitation of the central nervous system (Roldan and Dostalek, 1983, 1985) and brain epileptisation (Jaseja, 2005, 2006a,b; Nicholson, 2006; Lansky and St Louis, 2006). From a clinical study of twenty-seven long-term meditators, Shapiro (1992) found that 62.9% of them reported at least one adverse effect, and 7.4% suffered profound adverse effects. The adverse effects included relaxation-induced anxiety and panic, paradoxical increases in tension, less motivation in life, depression, increased negativity, boredom, pain, impaired reality testing, confusion and disorientation, feeling “spaced out”, and being more judgmental (Shapiro, 1992).

Hyperventilation practiced during some meditation techniques (for example, Sudarshan Kriya) may reduce cerebral blood flow by as much as 50% due to a central neurogenic response to hypocapnia mediated by the brain stem (Patel and Maulsby, 1987). This inhibitory effect on the mesencephalic reticular formation of the brain results in modified brain cortical activity that is indicative of ischemia. Furthermore, hyperventilation might be associated with induced typical absence seizures (Prevett et al., 1995), increase in cortisol and human growth hormone (Djarova et al., 1986) – both related to depression (Brown et al., 1999), and decreased attention and cognitive function (Ley, 1999; Van Diest et al., 2000).

There are several case reports of acute psychotic illness occurring in people who attend certain meditation/Yoga courses (Bharadwaj, 2012). The set of mental and psychological difficulties induced by intense or excessive practice of meditation/Yoga has been termed the “Physio-Kundalini Syndrome” (Turner et al., 1995). Spiritual emergency states is another example of adverse reactions characterized by an uncontrolled emergence of spiritual phenomena (Turner et al., 1995). Kundalini symptomatology and states of spiritual emergency may lead to a significant disruption in everyday psychological/social/occupational functioning of people who are experiencing them (Greyson, 1993, 2000). Even though Kundalini symptoms may, or may not, be associated with psychopathology, they could precipitate forms of mental disorders or exacerbate pre-existing psychiatric conditions (Turner et al., 1995; Scotton, 1996). This problem is recognized clinically and is included in the Diagnostic and Statistical Manual of Mental Disorders (DSM) as ‘Qi-gong Psychotic Reaction’, described as “an acute, time-limited episode characterized by disassociative, paranoid or other psychotic or non-psychotic symptoms [...]. Especially vulnerable are individuals who become overly involved in the practice” (American Psychiatric Association, 1994, p. 847).

It has been noticed that constitutional variables of a person, such as affective valence, introversion versus extroversion, anxiety level and many other could alter the outcome of meditation (Murata et al., 2004; Takahashi et al., 2005) and may transfer the positive effects into negative. For example, persons with depression or past experiences of trauma, may find themselves feeling increasingly anxious during meditation, no matter how much they try to focus on the current moment.

2.3. Positive meditation effects that could become negative

Some of the effects of meditation that are usually considered positive could become maladaptive and negative if overexpressed in individuals with a particular set of constitutional neurophysiological characteristics. For instance, long-term meditators have been shown to have higher pain tolerance and reduced feeling of unpleasantness of painful stimuli compared to non-meditators (Grant and Rainville, 2009; Zeidan et al., 2011). This trained feature could lead to serious problems in certain circumstances, since pain has an important adaptive function: it motivates the person to withdraw from damaging situations, to protect a damaged body part while it heals, and to avoid similar experiences in the future (Winlow and Holden, 1984). Insensitivity to pain may lead to increased risk of tissue damage due to undiscovered injury, which is usually accompanied with carelessly repeated damage to the tongue, eyes, joints, skin, and muscles (Nagasako et al., 2003).

Another trained feature observed in meditators is an enhancement of introspection (Fox et al., 2012; Sze et al., 2010), that leads to the ability to observe thoughts and emotions, as well as different objects in the world in a detached, dispassionate and selfless manner (Fox and Christoff, 2014). If such a feature is overexpressed it could lead in some neurophsyiologically predisposed persons to a “psychotic world-view” similar to the one found in schizophrenics. Schizophrenia (a form of psychosis) is characterized by a fundamental disintegration in conscious experience and fragmentation in the sense of self, by the inability to coherently integrate thoughts and perceptual information (for a review see, Uhlhaas and Silverstein, 2005; Uhlhaas and Mishara, 2007).

Activity of orbitofrontal cortex (OFC) is often enhanced in meditators (Klimecki et al., 2012; Westbrook et al., 2013). OFC is implicated in emotion regulation, specifically in down-regulating and reappraising negative emotional states (Ochsner et al., 2004; Goldin et al., 2008). This beneficial feature could turn into a maladaptive schema of behavior when it becomes rigidly overexpressed. For example, it could lead to a mania or a borderline personality disorder (Hayes et al., 1996; Gratz et al., 2006) with an inability to feel compassion or empathy (Taylor et al., 1997).

Functional neuroimaging studies using PET and fMRI have shown enhanced activity or larger volume of the hippocampus in meditators (Lou et al., 1999; Luders et al., 2009; Engström et al., 2010). Recent research suggests that such enhancement of hippocampus could lead to the reactivation of memories and exaggerated self-esteem (Nader et al., 2000; Debiec et al., 2002). This trained feature, if overexpressed in individuals with a particular neuropsychological types, could lead to serious problems, related to obsessive and intrusive thoughts, dissociation and flashbacks, all of which may be related to hippocampal over-enhancement (Levy and Anderson, 2008).

It has been documented that long-term meditation practitioners have reduced activation and diminished functional connectivity within the default mode network regions of the brain (Brewer et al., 2011; Fell, 2012). Given that default mode network integrity and activity are linked to a ‘sense of self’ (Schilbach et al., 2008; Fingelkurts and Fingelkurts, 2011), this could be interpreted as indication of weakening of that function. While this may confer functional benefits to meditators (Kang et al., 2013), there is a risk of depersonalization and loss of personality in some neuropsychologically predisposed individuals.

As for current advances along these lines, there is a clear understanding that any meditation practice, while being important for physical and mental wellbeing due to its multiple beneficial effects, may have undesirable effects in individuals with specific neuropsychological types (Lustyk et al., 2009).

3. Personalizing meditation

Considering the wide range of possible meditation techniques and resulting mental states, it seems likely that different practices will produce different brain-mind effects and that individuals with different neuropsychological types will respond differently. Some of these responses could be classified as meditation side effects with adverse reactions (Shapiro, 1992). As such these facts raise concern about suitability of every particular meditation/yoga technique for a given individual. It seems that not every meditation/yoga technique is suitable for everyone. This then leads to the next crucial question of understanding which technique confers the greatest benefit and is safe. A growing body of research suggests that assessment of brain function may be useful in this respect (Cahn and Polich, 2006; Saggar et al., 2012).

Contemporary neuroscience increasingly regards health of the brain as a key to mental and general health, especially in light of new discoveries on the brain's compensatory properties for weak function of vital organs of the organism (Ewing et al., 2007). Furthermore, the brain's neurophysiology and functioning determine the type of its functional state and related psychological and behavioral reactions. Therefore, if one could objectively measure such functional state of the brain, he/she could get knowledge about one's neuropsychological type. In this regard the objective assessment of brain functional state through a non-invasive electroencephalogram (EEG) procedure could be most helpful, allowing to identify the individuals who are most likely to exhibit positive alterations in psychophysiological functioning during concrete technique of meditation/yoga. Such EEG-guided approach would guarantee a safe and efficient use of meditation as a therapeutic or self-regulating procedure.

3.1. EEG-guided meditation

Quantitative EEG (qEEG) is digitally recorded and statistically analyzed electrical activity generated by the brain (Hughes and John, 1999). In general, EEG is obtained using electrodes placed on the scalp with a conductive gel. In the brain, there are millions of neurons, each of which generates small electric voltage fields. The aggregate of these electric voltage fields create an electrical reading, that electrodes on the scalp are able to detect and record (Niedermeyer and da Silva, 2004). More specifically, qEEG measures a highly organized macrolevel electrophysiological phenomena in the brain, which capture the operations of large-scale cortical networks (neuronal assemblies) and which are remarkably correlated with behavior, cognition, and consciousness (Nunez, 2000; Fingelkurts and Fingelkurts, 2010b; Fingelkurts et al., 2010, 2012).

As such qEEG technique has been recognized to reflect the functional state of the brain, levels of cognitive engagement, cognitive processing, skill integration, information recall, regulation of arousal and emotion (just to mention a few) (Corsi-Cabrera et al., 1989; Lehmann, 1990; Arieli et al., 1996; Nunez, 2000; Bressler and Kelso, 2001). In addition to detecting the functioning of neuronal processes and having a high temporal resolution qEEG has the ability to reveal the multidimensional structure of the brain's functional states through reference to different frequency components that vary in their functional significance (for the review see Lazarev, 2006). To date more than 4000 studies proved the stability and specificity of certain qEEG parameters (PubMed, 2014). These parameters were being studied quantitatively in large samples of healthy functioning individuals across different nations and wide age ranges. Numerous studies confirmed the high specificity of normative distributions of qEEG parameters within delta (0.5-3 Hz), theta (3.5-7 Hz), alpha (7.5-13 Hz), and beta (13.5-30 Hz) frequency bands (for the review see Basar, 1998; Gevins, 1998). Positive findings different from the normative databases in healthy, normally functioning individuals have repeatedly been shown to be within chance levels, with very high test-retest reliability (Thatcher and Lubar, 2008). The independence of the normative qEEG descriptors from cultural and ethnic factors enables objective assessment of brain integrity in individuals of any age, origin or background. Usually, a statistically significant deviation of qEEG parameters from a normalized reference range is indicative of dysfunctions and/or abnormalities associated with neurological, developmental, and psychiatric disorders (Thatcher and Lubar, 2008).

Numerous studies demonstrated that qEEG characteristics can confound functionally different psychophysiological determinants (for the review see Lazarev, 2006). Given the extensive data on frequency-dependent functional meaning of EEG oscillatory activity (John et al., 1977; Arroyo et al., 1993; Klimesch, 1996, 1999; Klimesch et al., 1998; Pfurtscheller et al., 1996; Bullock, 1997; Doppelmayr et al., 1998; Basar, 1998, 1999, 2008; Gevins, 1998, 2002; Pulvermuller et al., 1999; Basar et al., 2001a,b,c; Knyazev et al., 2005), different aspects of EEG oscillatory activity may help reveal which types of brain functioning are involved in mental activity. In this sense qEEG is a "natural" and noninvasive window into the human brain. Using advanced qEEG analysis in context of these studies it is possible to objectively quantify such mental aspects of performance like focus and attention, speed of information processing, stress regulation, emotions and overall brain resources (Fingelkurts et al., 2006; Fingelkurts and Fingelkurts, 2010a,b, 2015). By comparing qEEG parameters before and after a particular course of meditation (or any other training) it is possible to obtain objective results on how any given meditation type (or any other training) affects different brain-mind functions in every concrete individual.

As scientific studies have shown, various meditative states that are reached through practicing of a particular meditation technique are associated with different EEG spatio-temporal and oscillatory signatures and these signatures are directly related to the *baseline* neuropshychological profiles of practitioners (Lobusov et al., 2001; Murata et al., 2004; Takahashi et al., 2005; Cahn and Polich, 2006; Saggar et al., 2012). The results for EEG markers of different meditation techniques are summarized in Table 1. It can be seen that despite some heterogeneity, the most consistent results include alpha and theta power increase as well as the enhancement of alpha and theta coherence. Some studies also found a decrease in alpha frequency. Interestingly, many of the EEG characteristics are different in meditators compared with non-meditator controls already at the baseline resting condition (before meditation), which indicates that neurophysiological individuality of a subject is involved (Andresen, 2000; Aftanas and Golocheikine, 2001, 2002; Lobusov et al., 2001; Aftanas and Golosheykin, 2005). The baseline resting condition most likely reflects the individual's characteristic balance of the corresponding neurophysiological processes (Zhirmunskaya and Makarova, 1975; Lazarev, 2006; Fingelkurts and Fingelkurts, 2010b). Changes in this balance during a concrete type of mental activity must determine the corresponding functional state. Furthermore, both individual differences and functional states can be psychophysiologically interpreted in the same terms that characterize the individual's style in some aspects of mental activity performance (Lazarev, 2006). Therefore, if one knows in advance his/hers individual EEG profile, he or she (or coaching staff and trainer) could choose or adjust the meditation/yoga technique which would be the most suitable, and in such way could diminish the risk of possible negative effects. Likewise, use time-laps qEEG profile one can capture any negative changes early on. In this context, if neurophysiological information (derived from qEEG screening) is used as the independent variable and meditation response is analyzed as the dependent variable, a connection between neurophysiology and the meditation outcome may be observed.

3.2. qEEG screening

qEEG screening was designed to measure key mental/cognitive elements that contribute to the performance of an individual (meditator, athlete, manager or military personnel). Notice that measurement of the brain response to meditative practice is based on the premise that meditation induces distinct *states* and *traits* effects (Cahn and Polich, 2006). State refers to altered sensory, cognitive, and self-referential awareness that can arise during meditation practice, whereas trait refers to lasting changes in these dimensions that persist in the meditator irrespective of being actively engaged in meditation. Designed qEEG screening measures trait (long-term) effects of meditation. qEEG screening resulted in a 'qEEG screening' profile that presents the physiological state of the practitioner's brain and mind function described by a number of metrics related to key mental/cognitive elements. The output metrics and their scales provide an easy to understand quantitative parameters for otherwise complicated neurophysiological constructs.

Table 1. Summary of Electroencephalographic (EEG) effects of different meditation techniques.

EEG findings		Meditation technique	Study	Number of studies
alpha power	↓	Kriya Yoga; Tibetan Buddhism; Ananda Marga; Zen; Qigong; Sahaja Yoga	Das & Gastaut, 1955; Lobusov et al., 2001; Lehmann et al., 2012	3
alpha power	↑	Yoga; Raj Yoga; Zen; TM; Ananda Marga; Passive Meditation; Qigong; Santhi Kriya Yoga; Tibetan Buddhism; Mantra; Mindfulness; Kundalini Yoga; Sahaja Yoga	Wenger & Bagchi, 1961; Anand et al., 1961; Kasamatsu & Hirai, 1966; Wallace, 1970; Wallace et al., 1971; Banquet, 1973; Williams & West, 1975; Ghista et al., 1976; Elson et al., 1977; Corby et al., 1978; Lehrer et al., 1980; Farrow & Hebert, 1982; Taneli & Krahne 1987; Saletu, 1987; Zhang et al., 1988; Travis, 1991; Satyanarayana et al., 1992; Echenhofer et al., 1992; Deepak et al., 1994; Lee et al., 1997; Dunn et al., 1999; Kamei et al., 2000; Khare & Nigam, 2000; Arambula et al., 2001; Litscher et al., 2001; Travis, 2001; Travis et al., 2002; Aftanas & Golocheikine, 2001, 2002, 2003; Takahashi et al., 2005; Aftanas & Golosheykin, 2005; Yamamoto et al., 2006; Qin et al., 2009	35
alpha frequency	↓	Zen; TM; Qigong; Sahaja Yoga; Shamatha	Kasamatsu & Hirai, 1966; Wallace, 1970; Wallace et al., 1971; Banquet, 1973; Zhang et al., 1988; Aftanas & Golocheikine, 2001, 2002, 2003; Saggar et al., 2012	9
alpha frequency	↑	Kriya Yoga; Zen; TM	Kasamatsu & Hirai, 1966; Hirai, 1974; Das & Gastaut, 1955; Taneli & Krahne, 1987	4
alpha coherence	↑	TM; Qigong; Yoga; Zen	Dillbeck & Bronson, 1981; Orme-Johnson & Haynes, 1981; Farrow & Hebert, 1982; Badawi et al., 1984; Dillbeck & Vesely, 1986; Zhang et al., 1988; Gaylord et al., 1989; Travis, 1991; Travis & Wallace, 1999; Khare & Nigam, 2000; Travis, 2001; Travis et al., 2002; Hebert & Tan, 2004; Murata et al., 2004; Travis & Arenander, 2006; Travis et al. 2009	16
alpha coherence	↓	Tibetan Buddhism; Ananda Marga; Zen; Qigong; Sahaja Yoga	Lenmann et al., 2012	1
theta power	↑	Zen; TM; Ananda Marga; Self regulation; Tibetan Buddhism; Concentrative Qigong; Mindfulness; Sahaja Yoga; Vipassana; Tai Chi Chuan	Kasamatsu & Hirai, 1966; Wallace et al., 1971; Banquet, 1973; Tebecis, 1975; Ghista et al., 1976; Hebert & Lehmann, 1977; Fenwick et al., 1977; Elson et al., 1977; Corby et al., 1978; Warrenburg et al., 1980; Pagano & Warrenburg, 1983; Badawi et al., 1984; Saletu, 1987; Ikemi, 1988; Echenhofer et al., 1992; Pan et al., 1994; Dunn et al., 1999; Travis, 2001; Travis et al., 2002; Aftanas & Golocheikine, 2001, 2002, 2003; Takahashi et al., 2005; Aftanas & Golosheykin, 2005; Cahn et al., 2010; Baijal & Srinivasan, 2010; Field et al., 2010	27

theta coherence	↑	TM; Qigong; Sahaja Yoga; Zen	Badawi et al., 1984; Zhang et al., 1988; Gaylord et al., 1989; Travis, 2001; Aftanas & Golocheikine, 2001; Travis et al., 2002; Aftanas & Golocheikine, 2002, 2003; Faber et al., 2004; Baijal & Srinivasan, 2010	10
theta coherence	↓	Tibetan Buddhism; Ananda Marga; Zen; Qigong; Sahaja Yoga	Lehmann et al., 2012	1
beta power	↑	Kriya Yoga; TM; Tibetan Buddhist gTum-mo (heat generating); Mindfulness; Tibetan Buddhism; Ananda Marga; Zen; Qigong; Sahaja Yoga	Das & Gastaut, 1955; Banquet, 1973; Benson et al., 1990; Dunn et al., 1999; Lobusov et al., 2001; Lehmann et al., 2012	6
beta power	↓	Self regulation; Matra-based Relaxation; Shamatha	Ikemi, 1988; Jacobs et al., 1996; Saggar et al., 2012	3
beta coherence	↑	TM	Badawi et al., 1984; Travis et al., 2009	2
beta coherence	↓	Tibetan Buddhism; Ananda Marga; Zen; Qigong; Sahaja Yoga	Lehmann et al., 2012	1
gamma power	↑	Tibetan Buddhism; Love-Compassion; Ananda Marga; Zen; Qigong; Vipassana; Sahaja Yoga	Kasamatsu & Hirai, 1966; Banquet, 1973; West, 1980; Lehmann et al., 2001; Lutz et al., 2003, 2004; Cahn et al., 2010; Lehmann et al., 2012	8
gamma coherence	↑	Tibetan Buddhism; Zen; Love-Compassion	Lutz et al., 2003, 2004; Faber et al., 2004	3
gamma coherence	↓	Tibetan Buddhism; Ananda Marga; Zen; Qigong; Sahaja Yoga	Lehmann et al., 2012	1
mean EEG frequency	↓	TM	Stigsby et al., 1981	1
paroxysmal activity	↑	TM	Persinger, 1984; Jaseja, 2005, 2006a,b; Nicholson, 2006; Lansky & St Louis, 2006	6

These metrics are derived from a 19-channel EEG recording with a standard International 10-20 electrode placement system. The efficacy of such qEEG screening was tested in a pilot study on a group of subjects practicing meditation for the first time. qEEG data of each participant were compared to population normative reference (optimal range), stratified by age, and presented as *z*-

scores. A *z*-score is the difference between the mean score of a population (normative reference) and the individual's score divided by the standard deviation of the population. Statistically, *z*-scores quantify deviation of an observed value from optimal data. It expresses how much higher ($z > 0$: 'positive deviation') or lower ($z < 0$: 'negative deviation') the EEG values of the screened individual are in comparison with the mean value of matched normative data reference, in terms of standard deviation. Deviation from the optimal level was ranged from *slight*, *moderate, strong* to *very strong*. There is abundant evidence that optimal range derived from population normative qEEG values is the result of autoregulation of brain electrical rhythms by a complex homeostatic system, which is independent of ethnic or cultural factors (John and Prichep, 1993; John et al., 1988). In this context the *optimal range* of EEG characteristics represents certain ideal characteristics displayed by a majority of subjects in the same age group, without current or past neurologic or mental complains, without family history of neurologic and psychiatric diseases, or other illnesses that might be associated with brain dysfunction (Jirmunskaya and Losev, 1980). Description of some population normative qEEG values can be found for example in the Atlas of EEG Patterns (Stern and Engel, 2013). Notice that deviation from the optimal range does not necessarily reflect abnormality or a pathological process. Deviation means that the brain functions outside the optimal range, thus spending more energy and resources to achieve needed results/aims. If compensatory mechanisms of the brain are intact, then the qEEG characteristics deviation is pathogenically insignificant. However, the pathogenic significance of qEEG deviations from optimal range increases when compensatory mechanisms of the brain are exhausted (Jirmunskaya and Losev, 1980). This is usually associated with strong and very strong deviations from the optimal level.

qEEG screening profile consists of nine evaluation metrics: (1) *Tonus level* (activation/arousal/vigilance), (2) *Speed of cognitive and memory performance*, (3) *Internal concentration*, (4) *Positive vs negative emotional experience*, (5) *Sociability*, (6) *Anxiety*, (7) *Stress-resistance*, (8) *Overall brain resources*, and (9) *Deviation from optimal brain state*. Below is a brief description of each metric.

1. The tonus level metric reflects adequate loading of the regulatory systems of the brain that are required to fulfill the tasks.

2. The speed of cognitive and memory performance metric reflects the speed of information processing (information encoding and retrieval). At the behavioral level this characteristic determines a speed of reaction time.

3. The internal concentration metric reflects the cognitive process of selectively concentrating on one aspect of the internal environment while ignoring others. It indicates the intensity of a person's

level of mental “focus” or “attention”, such as that, which occurs during intense concentration and directed (but stable) mental activity.

4. The positive vs negative emotional experience metric reflects the tendency to experience positive/negative emotions (pleasant/unpleasant feelings induced by commonplace events or circumstances).

5. The sociability metric reflects the likelihood of engaging and interacting well with others (being sociable or social).

6. The anxiety metric is constructed to reflect a person’s readiness to process information and mobilize resources in anticipation of a difficult task or threat. It indicates if the individual is predisposed to overreact to external stimuli through unspecific excitement patterns of behavior.

7. The stress-resistance metric reflects the person’s adaptability to stress and ability to recuperate afterwards.

8. The overall brain resources metric reflects the ability to execute or complete a required function quickly, effectively (with minimum mistakes) and energetically wise, or to work effectively for a long time without fatigue. It demonstrates how optimal the information processing is and how much energy is wasted.

9. The deviation from optimal brain state metric reflects probable brain dysfunction.

Thus this nine-metric profile provides detailed information on the performance-relevant aspects of cognition for any given individual. When obtained before the training program, it allows to understand what are the baseline cognitive and neurophysiological demands of the individual and choose/adjust the training program accordingly. The intermediate and final testing provide the information about the dynamics of the values for each metric of the profile and thus allow to individual, coaching staff, and trainers to monitor progress with the aim of reaching optimal range for each metric. Different meditation practices and their various aspects are classified by its influence on qEEG information. In this way individual, coaching staff, and trainers are furnished with a physiological link between the meditation elements and their effects on brain function across diverse behavioral and mental expressions. Using these associations, meditation recommendations are made.

To evaluate the feasibility of qEEG screening for personalizing meditation protocols qEEG screening has been applied to 10 healthy, right-handed naïve participants (average age = 51.7 ± 10.9, four males) free of psychiatric disorders or history of head trauma, who did not take psychoactive medication and were not drug users, and had normal or corrected to normal vision. Prior to EEG scanning participants signed informed consent after the experimental procedures were explained. The study complied with the Code of Ethics of the World Medical Association (Declaration of Helsinki) and standards established by the BM-Science – Brain and Mind Technologies Research Centre Board.

The use of the data for scientific studies was authorized by means of written informed consent of the subjects. The participants' first EEG was recorded with 19 electrodes during 12 min (6 min closed eyes and 6 min open eyes) of baseline condition and the initial qEEG screening profile was generated from the qEEG analysis for every participant. Then, based on the individual's qEEG screening profiles, a personalized protocol was designed for every participant. Meditation training lasted 4 months and required 20 minute of daily meditation. The second EEG was recorded within one week after the meditation training has been terminated, generating a final qEEG screening profile. The 9 metrics of the qEEG screening profiles were examined by comparing how they change as a function of meditation. The following preliminary group results have been obtained. In general, vast majority of participants and vast majority of metrics have improved. There were no participants without improved metrics. Moreover, the more a metric deviated from the optimal range in the first measurement, the better improvement it demonstrated in the second assessment. Additionally, the younger the participant was, the better initial EEG was and a larger number of metrics improved in the end.

Specifically, the following functions have been *improved* (moved toward optimal level) after EEG-guided meditation:

- 'positive emotional experience' (in 80% of participants);
- 'stress-resistance' (in 70% of participants);
- 'deviation from the optimal brain state' (in 90% of participants);
- 'internal concentration' (in 90% of participants);
- 'anxiety' (in 60% of participants);
- 'sociability' (in 60% of participants);
- 'tonus level' (in 70% of participants);
- 'speed of cognitive and memory performance' (in 70% of participants);
- 'overall brain resources' (in 70% of participants).

The following functions *reached the optimal level* after EEG-guided meditation:

- 'overall brain resources' (in 90% of participants);
- 'stress-resistance' (in 60% of participants);
- 'anxiety' (in 50% of participants);
- 'tonus level' (in 50% of participants);
- 'speed of cognitive and memory performance' (in 50% of participants);
- the remaining metrics reach optimal level in 30% of participants.

Summarizing, personalized EEG-guided meditation not only improved EEG and brain functions but also shifts brain activity toward the optimal level.

How well the EEG-based personalization of meditation works can be illustrated on the individual data that contrast non-personalized *vs* personalized meditation. Figure 1 presents two examples of the qEEG screening performed individually. One participant practiced meditation technique without considering the baseline qEEG screening information, while the other participant practiced meditation which has been adjusted specifically for that participant based on insights obtained from qEEG in the initial (baseline) screening, thus been personalized. Both participants practiced their meditation sessions daily for 20 minutes during 4 months. The second qEEG screening has been performed within one week after the meditation training has been terminated.

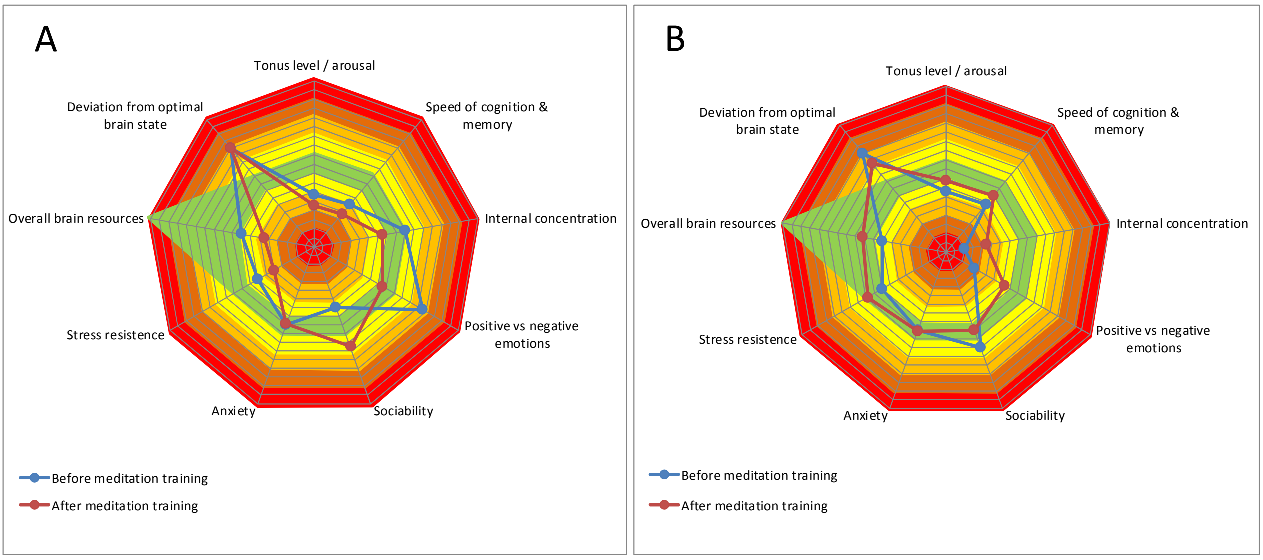

Figure 1. Example of the EEG screening results before and after meditation training. *A* – Participant practiced an arbitrary chosen meditation program (non-personalized). *B* – Participant practiced mediation that has been adjusted based on the baseline EEG screening results (personalized). Green color represents the optimal range, yellow color represents a slight deviation from the optimal range, light orange color represents a moderate deviation from the optimal range, dark orange color represents a strong deviation from the optimal range, and red color represents a very strong deviation from the optimal range.

Initially (at baseline) both participants had most metric values out of the optimal range (green area) with only two metrics within optimal range and one additional metric approaching optimal range (Fig. 1). After meditation training in the participant who practiced non-personalized meditation, only the "positive vs negative emotions" metric reached optimal range, while all other metrics either did not change or deviated even further from the optimal range. However, the participant who practiced personalized meditation showed improvement in all metrics, among which 6 reached optimal values (Fig. 1). These examples suggest that personalized meditation is more effective than an arbitrarily assigned one and thus may diminish or even avoid potential adverse side effects.

Taken as a whole, the described results suggest considerable improvement in the brain-mind functions (measured by screening metrics) as an outcome of personalized EEG-guided meditation training. Available pilot data suggested that qEEG screening may allow coaches and trainers to design maximally effective mediation/yoga training protocols, using information about the practitioners’ brain-mind strengths and weaknesses. Despite such promising results, they are preliminary and future studies with a larger sample of participants and different controls are necessary to formally evaluate validity, reliability and sensitivity of such an approach.

4. Conclusion

Summarizing, meditation may offer considerable promise as a safe, effective and relatively inexpensive intervention for reducing chronic stress and stress-related disorders, in addition improving cognition, mood, sleep, and general well-being. However, despite the documented therapeutic potential of meditation, the possibility of adverse effects warrants a discussion on the suitability of any particular meditation practice for all participants. A ‘one-size-fits-all’ approach may be ill advised in meditation/yoga training: each individual has different cognitive demands and different starting points. This highlights the need for a personalized approach to meditation practice. One way to do this could be achieved by applying an objective screening procedure that highlights the weak and strong cognitive skills of brain function, and thus provide a reliable guide for selecting the personalized meditation training protocol. qEEG offers such a possibility because it allows identification of the individual’s psychophysiological type which can be used to design a meditation training program that maximizes the efficacy and minimizes risk of potential negative effects. In this context, the synthesis of neurophysiology and neuropsychology has opened a new horizon for meditation/yoga, when the concrete meditation/yoga technique can be selected for a given individual based on the objective qEEG screening information obtained from the same individual.

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