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Review

Focused attention, open monitoring and automatic self-transcending: Categories to organize meditations from Vedic, Buddhist and Chinese traditions

Fred Travis [a,b,*], Jonathan Shear [c]

[a] Center for the Brain, Consciousness, and Cognition, Maharishi University of Management, 1000 North 4th Street, Fairfield, IA 52557, United States
[b] Maharishi University of Management Research Institute, Maharishi Vedic City, IA 52557, United States
[c] Department of Philosophy, Virginia Commonwealth University, 817 West Franklin Street, Richmond, VA 23284-9002, United States

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ABSTRACT

This paper proposes a third meditation-category—*automatic self-transcending*— to extend the dichotomy of *focused attention* and *open monitoring* proposed by Lutz. *Automatic self-transcending* includes techniques designed to transcend their own activity. This contrasts with f*ocused attention*, which keeps attention focused on an object; and *open monitoring*, which keeps attention involved in the monitoring process. Each category was assigned EEG bands, based on reported brain patterns during mental tasks, and meditations were categorized based on their reported EEG. *Focused attention*, characterized by beta/gamma activity, included meditations from Tibetan Buddhist, Buddhist, and Chinese traditions. *Open monitoring*, characterized by theta activity, included meditations from Buddhist, Chinese, and Vedic traditions. *Automatic self-transcending*, characterized by alpha1 activity, included meditations from Vedic and Chinese traditions. Between categories, the included meditations differed in focus, subject/object relation, and procedures. These findings shed light on the common mistake of averaging meditations together to determine mechanisms or clinical effects.

1. Introduction

Meditation practices are embedded in different cultures, worldviews, and traditions, which confounds discussions between meditation traditions. Neuroscience provides the language of brain functioning to discuss meditation practices. Brain patterns reflect the cognitive processes used in meditation practices (attention, feeling, reasoning, visualization), the way these processes are used (minimal- to highly-controlled cognitive processing), and the objects of meditation (thoughts, images, emotions, breath) (see Shear, 2006). Thus, brain patterns could provide an objective "language" to discuss procedures and experiences resulting from different meditation practices.

Lutz has divided meditation practices into two categories: *focused attention* meditation, which entails voluntary and sustained attention on a chosen object, and *open monitoring* meditation, which involves non-reactive monitoring of the moment-to-moment content of experience (Lutz, Slagter, Dunne, & Davidson, 2008). We suggest a third category of meditation practice, *automatic self-transcending*, which includes techniques designed to transcend their own activity.

* Corresponding author. Address: Center for the Brain, Consciousness, and Cognition, Maharishi University of Management, 1000 North 4th Street, Fairfield, IA 52557, United States.
E-mail address: ftravis@mum.edu (F. Travis).

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The category of *automatic self-transcending* is marked by the absence of both (a) focus and (b) individual control or effort. Focus on a single object of experience and an orientation to monitoring changing objects of experience keeps the meditator involved with the procedures of the technique—these practices are not designed to transcend their activity. Focus and monitoring experience are active mental processes, which keep the brain engaged in specific processing—individual activity keeps the mind from transcending. Thus, *automatic self-transcending* appears to define a class of meditations distinct from both *focused attention* and *open monitoring*.

These three categories are not mutually exclusive within a single session or over the course of a life-time of meditation practice. *Focused attention* and *open monitoring* are combined in Zen, Vipassana and Tibetan Buddhism meditation traditions (Austin, 2006; Gyatso & Jinpa, 1995; Lutz et al., 2008). Also, with diligent practice over many years, *focused attention* meditations may lead to reduced cognitive control and could result in "effortless" concentration (Lutz et al., 2008; Wallace, 1999).

Each meditation-category can be distinguished by its associated cognitive processes. Since different cognitive processes are associated with activity in different frequency bands (von Stein & Sarnthein, 2000), each category can be assigned characteristic EEG frequency band(s). The brainwave patterns reported during each meditations technique could be used to assign meditations to categories. These grouping of meditations will allow us to understand these three categories in terms of differences in attentional control, subject/object relation, and the nature of different meditation procedures. The purpose of this categorization is to appreciate the nature of different practices and not to assign a "grade" or value judgment to each one.

2. Cognitive processing and EEG frequency bands

Different processing modules work in parallel during information processing (Varela, Lachaux, Rodriguez, & Martinerie, 2001). Low frequency rhythms (theta and alpha) reflect top-down information processing involving attention and working-memory retention, whereas high frequency rhythms (beta2 and gamma) reflect bottom-up processing of the contents of experience (Razumnikova, 2007). While all frequencies work in concert, individual frequencies can be associated with specific cognitive processes (von Stein & Sarnthein, 2000).

2.1. Gamma bands (30–50 Hz) and Beta 2 (20–30 Hz)

Gamma activity reflects local processing within short-range connections responsible for object recognition and so construction of the content of experience (Lubar, 1997; Singer, 1999). Synchronized gamma serves as a gain control for mental processing (Salinas & Sejnowski, 2001), enabling postsynaptic potentials to integrate and so direct downstream networks to bind the elements of sensory processing into a perceptual object (von Stein & Sarnthein, 2000). Gamma band activity closely follows local changes in brain blood flow and increases synaptic plasticity important for long term memories (Niessing et al., 2005). Gamma activity is higher when actively maintaining abstract visual shapes in short-term memory, and is higher in attended compared to unattended stimuli (Jensen, Kaiser, & Lachaux, 2007).

Beta2 activity also is reported during focused executive processing. For instance, EEG patterns during Remote Associate Tasks in comparison to Simple Associate Tasks—Remote Associate Tasks require more attention—are characterized as widespread increases of beta2 activity and decreases of frontal alpha1 coherence (Razumnikova, 2007). Consequently, meditation practices that involve highly focused attention to a specific object in the experiential field might lead to higher activity in the beta2 and gamma bands.

It should be noted, that gamma activity reported during meditation practice might be confounded by EMG artifacts. Researchers recorded EEG during an auditory oddball task on two subjects in the presence (one subject) and absence (other subject) of complete neuromuscular blockade, sparing the dominant arm. The recordings were conducted in a Faraday cage to eliminate external sources of high frequency EEG. EEG rhythms in the paralyzed subject had six times less power in the 25–30 Hz band, and 100 times less power in the 40–100 Hz band (Whitham et al., 2007). Thus, muscle contamination of the EEG is an important consideration in the interpretation of gamma EEG during meditation practices.

2.2. Beta1 band (13–20 Hz)

Cortico-thalamic feedback loops modulating attention operate in the beta1 frequency. Beta1 bursts shift the system to an attention state that consequently allows for gamma synchronization and perception (Wrobel, 2000). Beta1 activity arises from "regional" processes that develop between nearby macrocolumns (Lubar, 1997). Beta1 activity has been associated with binding of sensory qualities into a unified perception, such as the integration of visual and auditory information (Hanslmayr et al., 2007; von Stein, Rappelsberger, Sarnthein, & Petsche, 1999; von Stein & Sarnthein, 2000). Increase of temporal and parietal 13–18 Hz beta1 coherence was seen across recognition tasks involving pictures, spoken words and written words. Consequently, beta1 activity during meditation practices may play a role in creating the unity of meditation experiences and could be part of all three categories.

2.3. Alpha band (8–12 Hz)

Alpha power has been considered a sign of cortical idling (Pfurtscheller, Stancak, & Neuper, 1996). High alpha activity in sensory and motor areas has been correlated with lower thalamic activity and lower posterior cerebral metabolic rate during eyes-closed rest (Oakes et al., 2004). The association of higher alpha activity with reduced cortical excitability is supported by reports of longer latency evoked potentials (Sauseng, Klimesch, Gerloff, & Hummel, 2009) and degraded perception of incoming stimuli (Thut & Miniussi, 2009) with higher posterior alpha power. Higher posterior alpha power may play a role in perceptual tuning of sensory areas in anticipation of visual events by deactivating brain areas involved in irrelevant processing (Ergenoglu et al., 2004; Rihs, Michel, & Thut, 2007).

This classical understanding of alpha as cortical idling holds for simple *sensori-motor* tasks. In contrast, alpha activity in *association* cortices is reported to positively covary with task demands. This so-called 'paradoxical' frontal alpha is reported during tasks involving internally directed attention (Shaw, 1996) such as imagining a tune compared to listening to the same tune (Cooper, Burgess, Croft, & Gruzelier, 2006). Alpha activity in association areas may represent liveliness of the "screen of consciousness," which provides a context for grouping isolated elements into the unity of experience. For instance, when solving a problem by intuition or insight, alpha activity increases first, followed by increases in the gamma band when the idea comes to mind (Kounios & Beeman, 2009). Also, cross frequency coherence—the synchrony between alpha, beta and gamma—increases with higher cognitive load on a continuous mental arithmetic task. Cross frequency coherence is considered important for integrating anatomically distributed processing in the brain (Palva & Palva, 2007; Palva, Palva, & Kaila, 2005).

Alpha1 (8–10 Hz) versus alpha2 (10–12). Alpha1 and alpha2 activity desynchronize at different stages in an oddball task, with a warning signal preceding target and non-target stimuli. Alpha1 desynchronized in response to the two warning signals and target; alpha2 desynchronized only after the target was presented (Klimesch, Doppelmayr, Russegger, Pachinger, & Schwaiger, 1998). In another study, EEG complexity negatively correlated with frontal power in the theta and alpha1 bands, and positively correlated with power in the alpha2, beta, and gamma bands (Aftanas & Golocheikine, 2002). Alpha1 appears to index level of internalized attention, alertness and expectancy (Takahashi et al., 2005); alpha2 appears to index engagement of specific brain modules used in task performance. Consequently, we expect posterior alpha2 in any meditation that involves sitting with eyes-closed—classical cortical idling—and frontal alpha1 in any meditation that transcends its own activity.

2.4. Theta band (4–8 Hz)

Frontal midline theta, which originates in medial prefrontal and anterior cingulate cortices, is a neural index of monitoring inner processes (Vinogradova, 2001). Frontal midline theta is reported during tasks requiring self-control, internal timing, and assessment of reward (Ishii et al., 1999); during working memory tasks (Sarnthein, Petsche, Rappelsberger, Shaw, & von Stein, 1998); and during tasks requiring memory retention and mental imagery (von Stein & Sarnthein, 2000). Frontal midline theta activity increases a few seconds before a self-initiated hand-movement and reaches a peak immediately after the movement (Tsujimoto, Shimazu, & Isomura, 2006). Theta activity dynamically coordinates central executive circuits during serial subtraction (Mizuhara & Yamaguchi, 2007). Consequently, we expect frontal midline theta in a meditation that involves monitoring of ongoing experience without high levels of control or manipulation of the contents of experience.

2.5. Delta band (1–4 Hz)

Delta EEG around 1 Hz is the hallmark of slow wave sleep. The restorative value of sleep is linked to the periods of delta EEG when human growth hormone is secreted (Feinberg, 2000). The delta wave form is generated intracortically and supports synaptic plasticity in cortical neurons (Steriade, 2003).

Delta activity during waking is most often associated with pathology such as dementia (Babiloni et al., 2008). However, two meditation studies have reported changes in the delta band during meditation practice. One reported *lower* frontal delta power (Mindfulness Meditation, (Cahn, Delorme, & Polich, 2010)) and the other reported higher delta source localization as measured by eLORETA (Qigong (Tei et al., 2009)).

3. EEG patterns during different meditation practices

Meditation practices were assigned to a category by their reported EEG patterns. Table 1 contains the three meditation-categories and their suggested associated EEG frequency bands (left column), characteristic procedures of this meditation-category (middle band), and meditation practices that fit into each category as determined by reported EEG. Studies are listed in the table if they included a control group; if the meditation group had been meditating at least a few weeks to have begun to master the meditation practice; and if the technique practiced was a traditional meditation technique rather than a clinically-derived practice. Studies using single-group designs or case studies are summarized at the end of each category on the table. The studies are discussed in depth after the table. The implications of the groupings of meditation practices are explored in the general discussion.

3.1. Category: focused attention

In *focused attention* or concentrative styles of meditations, voluntary sustained attention is focused on a given object, and attention is brought back to the object of attention when the mind has wandered (Cahn & Polich, 2006; Raffone & Srinivasan, 2009). The meditator is controlling the contents in the beam of attention.

Table 1
Summary of meditation-categories and associated EEG frequency bands (left column), characteristic elements of each meditation-category (middle band), and meditation practices that fit into each category as determined by the published EEG patterns.

Meditation-category and EEG Band	Elements of these categories	Different meditation practices
Focused attention Gamma (30–50 Hz) and Beta2 (20–30 Hz)	• Voluntary control of attention and cognitive processes	• Loving-kindness-compassion (Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004): increased frontal-parietal gamma coherence and power • Other studies with single group or case study designs ○ Qigong: (Litscher, Wenzel, Niederwieser, & Schwarz, 2001) ○ Zen–3rd ventricle: (Huang and Lo, 2009) ○ Diamond Way Buddhism: (Lehmann et al., 2001)
Open Monitoring Theta (5–8 Hz)	• Dispassionate, non-evaluative awareness of ongoing experience	• Vipassana meditation (Cahn et al., 2010): decreased frontal delta, increased frontal midline theta and increased occipital gamma power • Zen meditation (ZaZen) (Murata, Koshino, & Ormari, 1994): increased frontal midline theta • Sahaja Yoga (Aftanas and Golocheikine, 2001): increased frontal midline theta and frontal-parietal theta coherence • Sahaja Yoga (Baijal & Srinivasan, 2009): increased frontal midline theta and coherence • Concentrative Qigong (Pan, Zhang, & Xia, 1994): increased frontal midline theta
Automatic Self-Transcending Alpha1 (8–10 Hz)	• Automatic transcending of the procedures of the meditation practice	• Transcendental Meditation technique (Dillbeck & Bronson, 1981): increased frontal alpha coherence • Transcendental Meditation technique (Travis et al., 2010): increased frontal alpha1 power and decreased beta1 and gamma power; increased alpha1 and beta1 frontal coherence; and increased activation in the default mode network • Transcendental Meditation technique (Travis & Wallace, 1999): increased frontal coherence in the first minute of TM practice and continued high coherence throughout the session • Transcendental Meditation technique (Travis, 2001): higher frontal alpha coherence during transcending • Transcendental Meditation technique (Travis & Arenander, 2006): higher frontal alpha1 coherence (cross-sectional design) and increasing frontal alpha coherence (1 year longitudinal design) • Transcendental Meditation technique (Hebert, Lehmann, Tan, Travis, & Arenander, 2005): enhanced anterior/posterior alpha phase synchrony • Other case study ○ Qigong (Qin, Jin, Lin, & Hermanowicz, 2009)

Note: All studies reported here used non-equivalent or matched control group designs, except for the first four studies on practice of the Transcendental Meditation technique, which used random assignment designs.

Loving-kindness-compassion (Tibetan Buddhist tradition) – higher gamma power and coherence. This study tested EEG patterns recorded during a neutral period and during meditation on unconditional loving-kindness-compassion described as an "unrestricted readiness and availability to help living beings" (Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004). EEG patterns in eight long-term Buddhist practitioners (average age 49 years), with 10,000–50,000 h meditation practice over 15–40 years, were compared to 10 healthy student volunteers (average age 21 years), with 1 week of meditation training. This was a non-equivalent control group design, with significant age differences between subjects. During meditation compared to controls, the long term subjects had (1) higher global gamma/theta-alpha (4–13 Hz) ratios; (2) 30 times higher parietal, temporal, and frontal gamma power; and (3) higher frontal-parietal gamma synchrony. There was a strong positive correlation between years of practice and relative gamma power ($r > 0.6$).

Other papers reporting activity in the gamma band—single group and case study designs. Three other papers reported increased gamma or beta2 activity during meditation from Chinese and Buddhist traditions. In one study, EEG was measured in a Qigong master (57 years old) and in an experienced female Qigong meditator (47 years old). Compared to eyes-closed rest, gamma activity increased and alpha activity dropped to near zero during meditation in both individuals. Brain blood flow also increased during meditation, as measured by near infrared spectroscopy (Litscher, Wenzel, Niederwieser, & Schwarz, 2001).

The next study investigated EEG in 23 experienced Zen meditators (average age 31.3 years) when concentrating on the third ventricle, the so-called "Zen chakra." This was a single-group design. During meditation, there was higher complexity in the EEG that was correlated with higher beta2 (20–30 Hz) activity. Frontal alpha power and occipital beta power were higher at the beginning of meditation; while beta2 (20–30 Hz) power was higher in the middle and end (Huang & Lo, 2009).

A third study investigated EEG patterns in a long term, advanced meditator, 59 years old, who was a Buddhist Lama of the Karma Kagyu lineage, teaching Diamond Way Buddhism. EEG was recorded during five meditations: (1) Buddha in front; (2) Buddha above, (3) verbalization of a 100-Syllable Mantra, (4) concentration on the experience of dissolution of the self into a boundless unity or emptiness; and (5) concentration on the experience of the reconstitution of the self (Lehmann et al., 2001). Increased gamma activity was seen in brain areas known to be involved in each type of cognitive processing: visual areas, verbal areas, and frontal areas for the 4th and 5th meditations.

Summary: In conclusion, beta2 and gamma activity have been reported during meditation practices from the Tibetan Buddhist, Chinese, and Buddhist traditions. Beta2 and gamma activity were reported when individuals created a vivid inner emotion, sustained focused on an area of the body, or created a strong visual image, and strictly monitored deviation of attention from that object.

3.2. Category: open monitoring

Open monitoring or mindfulness-based meditations, involve the non-reactive monitoring of the content of ongoing experience, primarily as a means to become reflectively aware of the nature of emotional and cognitive patterns (Raffone & Srinivasan, 2009). Open monitoring practices are based on an attentive set characterized by an open presence and a non-judgmental awareness of sensory, cognitive and affective fields of experience in the present moment and involves a higher-order meta-awareness of ongoing mental processes (Cahn & Polich, 2006).

Vipassana Meditation (Buddhist Meditation)—frontal theta and occipital gamma. One study has reported EEG patterns during Vipassana (Mindfulness) Meditation. This was a single-group design. It is included in this table, since it is the only published study on EEG patterns during Vipassana or Mindfulness Meditation. EEG was recorded during a neutral thinking period and during Vipassana meditation in 16 individuals who had practiced Vipassana meditation for an average of 20.0 years. This meditation included attentional scanning of sensations throughout the body in an iterative and cyclic fashion—scanning body sensations from the top of the head to the toes and back again repeatedly—with the concomitant adoption of an attitude of detached observation and non-reactivity to any sensations and thoughts that may arise. In both neutral and meditation conditions, posterior alpha power was higher than central or frontal power—with no differences in alpha between the two conditions. During meditation, (1) frontal theta (4–8 Hz) was higher; and (2) occipital (P8, O1, O2, and P7) gamma power was higher (Cahn et al., 2010). Gamma appeared in the four sensors on the periphery of the electro-cap, with P7 and P8 being in temporal rather than parietal cortices. This study is included in the *open monitoring* category, marked by theta activity, because theta increased during this meditation and the meaning of gamma power on the periphery of the recorded EEG is not clear.

Zen meditation (Zazen: Buddhist tradition)—higher frontal midline theta. This is the only published study using control groups that reports EEG findings during Zen meditation (Chiesa, 2009). This study tested EEG patterns recorded in 10 Buddhist monks with extensive experience, 10 monks with moderate experience, and 10 non-meditating controls prior to and during Zazen meditation. Only the long term group showed frontal midline theta during meditation compared to the short-term and control groups (Murata, Koshino, & Ormari, 1994). The level of theta correlated positively with years of experience.

Sahaja Meditation (Vedic tradition)—higher theta power and coherence. This study tested EEG patterns recorded in 11 short-term (<1 year) and 16 long-term practitioners (3–7 years) of Sahaja Meditation, a concentrative form of meditation that is part of Sudarshan Kriya yoga. Specific details of this practice are not available. The key experience during Sahaja meditation is a state called 'thoughtless awareness' or 'mental silence' defined as a state of alertness and awareness free of unnecessary mental activity. EEG was recorded before, during and after meditation. An eight-sec artifact-free window was selected from each period, and power and coherence were calculated and compared. The long-term meditators had significantly higher 3.8–5.7 Hz frontal power and frontal-parietal coherence, and significantly higher frontal 5.7–7.5 Hz power (Aftanas & Golocheikine, 2001). (The paper reported these results as changes in the "theta2" and "alpha1" bands. However, as you see, they were in the typical theta1 (4.0–6.0 Hz) and theta2 (6.0–8.0 Hz) bands.)

Sahaja Samadhi Meditation (Vedic tradition)—higher theta power and coherence. The finding of higher theta (5–8 Hz) power and coherence during Sahaja meditation was replicated in 10 teachers of Sahaja Samadhi meditation at the Art of Living Foundation compared to 10 age-matched subjects who did not practice any meditation techniques. The controls relaxed with eyes closed. The meditating subjects showed increased percentage frontal theta power and frontal theta coherence. Occipital and parietal theta power decreased (Baijal & Srinivasan, 2009).

Concentrative Qi-Cong (Chinese tradition)—higher midline frontal theta. This study tested EEG patterns recorded in 20 practitioners of concentrative Qigong, 30 practitioners of non-concentrative Qigong, and 23 control subjects. Relative to the other two groups, frontal midline theta rhythm was higher during the concentrative Qigong state (Pan, Zhang, & Xia, 1994).

Other papers reporting activity in the theta band—single-group designs. Three studies from the same laboratory have reported changes during a beginning Zen practice called Su-Soku—counting breathes guided by a metronome. These studies used the same subject population, undergradute students with no meditation experience, and measured EEG during their first day of meditation practice. These three papers reported different findings—theta in one study (Kubota et al., 2001), theta and alpha power in another (Murata et al., 2004), and alpha coherence in the third (Takahashi et al., 2005). Since the same design reported different findings with the same subject population, these finding may not be reliable. Thus, we did not include these three studies in the table and in the later discussion.

Summary. In conclusion, Vipassana meditation, as expected, fell in this category of *open monitoring*, and was characterized by higher frontal theta power. Higher theta power was also seen during ZaZen meditation, and higher theta power and coherence were reported in two studies on Sahaja meditation and one on concentration Qigong.

3.3. Category: automatic self-transcending

Automatic self-transcending practices involve transcending of the procedures of the meditation. Since cognitive control increases mental activity, self-transcending procedures would need to involve minimal cognitive control—be automatic or effortless. This is explored more in the discussion.

Transcendental Meditation (TM) practice—higher frontal alpha1 coherence. This random assignment study reported EEG patterns in eight subjects during Transcendental Meditation practice after 2 weeks practice compared to eyes-closed rest in seven subjects who rested twice a day for the 2 week period (Dillbeck & Bronson, 1981). Transcendental Meditation practice was marked by significantly higher frontal alpha coherence. There were no differences in alpha power or occipital power and coherence.

Transcendental Meditation (TM) practice—higher frontal alpha1 and lower beta1 and gamma power, higher frontal alpha1 and beta1 coherence, and greater activation in the Default Mode Network (eLORETA). This random assignment study reported EEG patterns in 19 subjects during Transcendental Meditation technique after 3 months practice compared to eyes-closed rest in 19 control subjects (Travis et al., 2010). Compared to eyes-closed rest, TM practice led to higher alpha1 frontal and lower beta1 and gamma frontal log-power; higher frontal and parietal alpha1 coherence and higher beta1 coherence; and eLORETA analysis identified sources of alpha1 activity in midline cortical regions that overlapped with the default mode network (DMN). The DMN is defined as an intrinsic default brain state, which is lower during goal-directed behaviors requiring executive control and higher during low cognitive load periods such as eyes-closed rest (Gusnard, Raichle, & Raichle, 2001; Raichle & Snyder, 2007), during self-referential mental tasks (Gusnard et al., 2001; Kelley et al., 2002; Vogeley et al., 2001), during tasks involving self-projection—mentally projecting oneself into alternative situations such as envisioning the future (Kelley et al., 2002; Vogeley et al., 2001), and when considering the viewpoint of others (Theory of Mind) (Buckner & Carroll, 2007). Greater activation in the DMN during TM practice suggests that the experience gained during this meditation may be one of greatly reduced cognitive load and heightened sense-of-self. This meditation state could be a foundational or 'ground' state of cerebral functioning that may underlie eyes-closed rest and more focused cognitive processes.

Transcendental Meditation (TM) practice—higher frontal alpha1 coherence. This random assignment within-subject study reported EEG patterns in 20 subjects during 10 min practice of the Transcendental Meditation technique compared to order-balanced 10 min eyes-closed rest periods (Travis & Wallace, 1999). The TM periods were distinguished by higher alpha1 frontal and frontal-parietal coherence. These differences were seen in the first minute of TM practice compared to eyes-closed rest, and continued throughout the 10 min session. No differences were seen in alpha power.

Transcendental Meditation (TM) practice—higher global alpha power and higher frontal alpha1 coherence. This random assignment within-subject study reported EEG patterns in 25 subjects during transcending compared to order-balanced periods of thought-filled experiences during Transcendental Meditation practice. Transcending was subjectively characterized by the absence of time, space and body sense (Travis & Pearson, 2000), and objectively characterized by: (1) significantly lower breath rates; (2) higher respiratory sinus arrhythmia amplitudes; (3) higher global alpha power; and (4) higher frontal alpha coherence (Travis, 2001).

Transcendental Meditation (TM) practice—higher alpha frontal coherence (cross-sectional and longitudinal designs). This study reported two experiments–one used a cross-sectional design and the other used a single group 1 year longitudinal design. In the cross-sectional study, frontal alpha1 coherence was higher in 13 TM subjects with 7 years average TM experience compared to 12 matched controls sitting with eyes closed. In the longitudinal study, frontal alpha1 coherence increased after 2 months' TM practice and reached that high level at 6 and 12 months posttests (Travis & Arenander, 2006).

Transcendental Meditation (TM) practice—enhanced anterior/posterior alpha phase synchrony. This matched control study compared alpha phase synchrony in 15 TM subjects with an average of 25 years TM practice to alpha phase synchrony in twelve control subjects without meditation experience. Significant increases in phase synchrony were found during the meditation condition as compared to the eyes-closed resting condition in long-range electrode pairings between frontal and parietal-occipital sites. There were no significant differences in alpha phase synchrony between the two eyes-closed resting periods in the controls. Enhanced alpha anterior/posterior phase synchrony during TM practice may improve functional integration and may have implications for performance and mind-body health (Hebert et al., 2005).

Other papers reporting activity in the alpha1 band—case study. A case study of a single practitioner of Qigong tested once and then 45 years later, reported that global alpha1 power increased immediately during Qigong practice on posttest, and remained higher at rest after the Qigong practice (Qin, Jin, Lin, & Hermanowicz, 2009).

Caveat on coherence. Since EEG is a difference-measure, coherence estimates are influenced by activity at both the active and reference electrodes. As the power at the active sensors becomes lower, so the contribution of a common reference will be larger in both signals leading to larger coherence values (Fein, Raz, Brown, & Merrin, 1988). While converting the data to a Laplacian or averaged reference removes the effect of the reference (Travis, 1994), it disrupts the network dynamics. The common reference—though leading to higher coherence values—maintains the coherence and phase synchrony relations among leads and so makes them more interpretable (Thatcher, North, & Biver, 2005). Thus, using a common reference allows better comparison between coherence pairs over the scalp, and any inflation of the coherence from the common reference would equally effect all conditions compared in the research.

Summary. Two different meditations were in this category—the Transcendental Meditation technique, described as a technique for automatic transcending (Maharishi Mahesh Yogi, 1969) and Qigong, which included a single meditator with extensive practice (45 years). The idea of automaticity is explored in the discussion. This category of *automatic* *self-transcending* refers to meditation techniques rather than subjective experiences. While these meditations may be automatic, the rate of transcending may vary, person-to-person, and often meditation-to-meditation, owing to differences in the mind and body when one sits to meditate.

4. Discussion

The three meditation-categories had different EEG patterns that were associated with different groups of meditation practices with distinct procedures involving different cognitive processes, different ranges of attention, and different subject/object content of experience. The meditations that were grouped under *focused attention* included meditations that involved voluntary sustained attention on a specific experience—creating a vivid emotion, a strong visual image, or focusing on a body area. The meditations grouped under *open monitoring* included Vipassana and ZaZen that involve open monitoring. Sahaja and Qigong meditations were also in this category though the details of these practices were not given in the papers. The meditations grouped under *automatic self-transcending* included Transcendental Meditation and Qigong. TM is described as being automatic in that one uses the "natural tendency of the mind" to transcend (Maharishi Mahesh Yogi, 1969; Travis et al., 2010). Qigong practice may have become automatic after diligent practice for 45 years. The implications of these groupings are discussed below.

It is interesting that the Transcendental Meditation technique, the most researched of the *automatic self-transcending* procedures, is often placed in the category of focused attention (Cahn & Polich, 2006; Raffone & Srinivasan, 2009). This raises question of the relation of the TM technique and *focused attention*. Also, it will be important to examine the notion of "automatic" transcending.

4.1. What is the relation of Transcendental Meditation to focused attention?

The reader may ask: why *focused attention* meditations and the Transcendental Meditation technique have different EEG patterns? TM can be superficially described as thinking or repeating a mantra—a word without meaning—and going back to it when it is forgotten (Raffone & Srinivasan, 2009)—this sounds similar to descriptions of focuse*d attention* techniques. A deeper analysis reveals that the TM technique is a technique for transcending its own procedures—appreciating the mantra at "finer" levels in which the mantra becomes increasingly secondary in experience and ultimately disappears and self-awareness becomes more primary (Maharishi Mahesh Yogi, 1969; Travis & Pearson, 2000). While focused arousal involves voluntary sustained attention, TM practice involves automatic moving of attention to mental silence. During TM practice, the subject-object relation that defines customary experiences is transcended. In *focused attention* the object of experience is sustained in awareness—the subject (experience) and object co-exist, they are independent but interact. In TM, the object of experience fades away—you use the mantra to lose it. When the mantra disappears, the subject, or the experiencer, as Maharishi puts it, "finds him/herself awake to his/her own existence" (Maharishi Mahesh Yogi, 1997).

4.2. Investigation of automatic transcending

Automatic and controlled processing have been investigated in psychology for the last three decades. In psychology, a task is automatic (1) if the response does not require controlled processing, does not require attention to the steps of responding; and (2) if performance is not affected by increasing task loads (Schneider, Pimm-Smith, & Worden, 1994). Research on automaticity has investigated automaticity through extensive rehearsal. Focused attention meditations when practiced over time are described as leading to "effortless" concentration (Lutz et al., 2008). This is automaticity resulting from long practice. If the category *automatic self-transcending* captures automatic transcending of the steps of techniques in general, then one might expect to find the EEG signature of this category–elevated alpha1 power and coherence–in any meditation after long practice. The case study reported here of 45 year Qigong practice supports this prediction (Qin et al., 2009). Future research should further investigate this prediction.

The TM technique is automatic at the outset, rather than through extensive practice. This is said to be because it uses the "natural tendency of the mind" to transcend perception of the mantra (Maharishi Mahesh Yogi, 1969). The automaticity of the TM technique is reflected in research reporting the lack of a novice/expert dichotomy among TM meditators, in contrast to research on other meditation traditions (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007). For instance, two cross-sectional studies —comparing individuals with 4 months versus 8 years TM practice (Travis, 1991) or individuals with 7 years versus 32 years TM practice (Travis, Tecce, Arenander, & Wallace, 2002)—report that brain wave patterns reach high levels during TM practice after a few months practice, and that progressive changes in EEG patterns are seen in activity after the meditation session, reflecting experience-related neuroplasticity integrating the meditation experience with daily activity (Travis, Tecce, & Durchholz, 2001).

5. Conclusion

Each of the three meditation-categories—*focused attention, open monitoring and automatic self-transcending*— included different meditation practices with different degrees of attention control, different degree of subject/object relations, and different procedures. Each category appears orthogonal to the others, and together they appear to reflect the wide range of possible meditation practices. These explicit differences between meditation techniques need to be respected when researching physiological patterns or clinical outcomes of meditation practices. If they are averaged together, then the resulting phenomenological, physiological, and clinical profiles cannot be meaningfully interpreted (see Luders, Toga, Lepore, & Gaser, 2009). Attention to these differences in meditation practices will clarify the results gained from researching the power of meditation practices to enhance development of mind and body.

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