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SPECIAL ISSUE

Neurophysiological Changes in Meditation Correlated with Descriptions from the Ancient Texts

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*Meditation is currently considered to be associated with increased awareness. In ancient yoga texts, two separate meditative states have been described. These are meditative focusing (*dharana*) and a state of mental expansiveness (*dhyana*). Two more mental states are described in another yoga text. These are random thinking (*cancalata*) and focusing while not in meditation (*ekagrata*). The physiological effects of these states have been assessed using autonomic variables, evoked potentials, functional magnetic resonance imaging, and performance in a cancellation task. The findings suggest that* dhyana *is associated with reduced sympathetic activity and increased vagal tone, whereas* dharana *does indeed improve performance in an attention task. Hence, correlating findings from ancient texts with contemporary science can be useful.*

Meditation was described early on as a training in awareness, which when practiced for some time leads to changes in perception, attention, and cognition (Brown, 1977). More recently, meditation has been recognized as a state of consciousness in which deep relaxation and increased internalized attention exist, simultaneously (Murata et al., 2004). Perhaps this is the reason why the concepts of directing and regulating attention are considered inherent parts of different meditation techniques (Davidson & Goleman, 1977).

The concepts of meditation described in ancient yoga texts are rather different, as meditation is not supposed to be associated with heightened attention or even of being aware of the experience as it happens. This is most clearly mentioned in the aphorisms (*sutras*) of the sage, Patanjali (ca. 900 B.C.). According to Patanjali, there are eight stages, which are to follow each other in sequence to lead to a stage of ultimate realization (Taimini, 1986). These eight stages are (i) and (ii) rules for good conduct (*yamas* and *niyamas*), (iii) physical postures (*asanas*), (iv) voluntarily regulated breathing (*pranayamas*), (v) withdrawal, particularly from external sensations (*pratyahara*), (vi) focused thinking (*dharana*), (vii) a defocused state of mental expansiveness (*dhyana*), and (viii) an experience of transcendence or ultimate realization (*samadhi*). While the ideal yoga practice would involve going from one stage to the other in sequence, there have been reports of benefits when novices to yoga practice begin with practicing yoga postures (Khattab, Khattab, Ortak, Richardt, & Bonnemeier, 2007) or voluntarily regulated breathing (Telles, Gaur, & Balkrishna, 2009). This also applies to meditation (Tang et al., 2007). The sixth (*dharana*) and seventh (*dhyana*) stages described by Patanjali are both meditative states.

The sixth stage (*dharana*) fits in with the known descriptions of meditation (Brown, 1977). *Dharana* means confining the mind within a limited mental area (''*desha-bandhashchittasya dharana*''; Patanjali's Yoga *Sutras*, Chapter 3, Verse 1). The description of *dharana* fits in with the contemporary categorization of meditation practices as two main styles (Telles, Naveen, & Balkrishna, 2010). This categorization is based on how attention is directed (Lutz, Slagter, Dunne, & Davidson, 2008). One category is called focused attention (FA), during which attention is sustained and focused on a given object. The second category is called open monitor meditation, where meditators are required not to react, while monitoring the content of ongoing experience. This style is a method by which the practitioner is aware of all mental content from one moment to the next. Both types of meditation styles require mental activity, though the nature of the activity is different. Specifically ''open monitor meditation'' does not involve a specific attentional focus, but involves brain regions that are active in disengaging attention from ongoing experience. Hence, while *dharana* does include the current descriptions of meditation, *dhyana* does not fit either category. Unlike *dharana*, which requires special effort, during *dhyana* there is no special focusing or effort. The description of *dhyana*, is as an uninterrupted flow of the mind toward the object chosen for meditation (''*tatra pratyayaikatanata dhyanam*''; Patanjali's Yoga *Sutras*, Chapter 3, Verse 2).

A series of experiments have been carried out to understand whether the physiological effects of *dharana* and *dhyana* are distinct and different. In these experiments, two more mental states described in another yoga text (the *Bhagavad Gita*, which was compiled ca. 500 B.C.) were considered as control sessions. The first was *cancalata* (*Bhagavad Gita*, Chapter 6, Verse 34; Sarasvati & Swami, 1998), which is a stage of random thinking. The second state was *ekagrata* (*Bhagavad Gita*, Chapter 6, Verse 12), during which the attention is directed to a number of associated thoughts. If a person chooses thoughts related to meditation, it would be easier for them to practice *dharana* and *dhyana*.

These studies were carried out on healthy male volunteers whose ages ranged between 20 and 55 years (group mean age $\pm$ SD, 29.0 $\pm$ 6.8 years). All of them were residing at a yoga center in South India and were actively engaged in studying yoga. Their normal health status was based on a routine case history and chemical examination.

While they were practicing other yoga techniques as well, all of them had a minimum of 6 months experience of meditation on the Sanskrit syllable, Om (group average experience $\pm$ SD, 22.5 $\pm$ 17.5 months). This meditation technique can be separately practiced as *dharana* (focusing on thoughts of Om) and *dhyana* (where the practitioner does not focus on Om but reaches an expansive mental state where all thoughts are about Om, but no effort is involved). Participants can be trained to practice the two techniques (*dharana* and *dhyana*) separately and at will. To ensure that all of them were doing it correctly, they were given a 3-month orientation course, during which time they were supervised by an experienced meditation teacher.

All participants were assessed in four sessions on four separate days, at the same time of the day. The four sessions were *dharana*, *dhyana*, *ekagrata* and *cancalata*. The evaluation of the participants' ability to attain these four mental states was based on their self-report (on a scale of 0 to 10), as well as on consultations with the meditation teacher.

The assessments included (i) autonomic variables and the breath rate, (ii) brainstem auditory evoked potentials, (iii) functional magnetic resonance imaging, and (iv) performance in a letter cancellation task. Each of these assessments and the results obtained will be discussed below in detail.

Autonomic Variables and the Breath Rate

The autonomic variables assessed included the heart rate, heart rate variability (for both time and frequency domain analysis), skin resistance, finger plethysmogram amplitude, and the breath rate. Assessment were made before (5 minutes), during (20 minutes), and after (5 minutes), the four practices. These were: (i) *dharana*, (ii) *dhyana*, (iii) *cancalata*, and (iv) *ekagrata*, practiced on four separate days. Data were analyzed using a repeated measure ANOVA and Bonferroni adjusted post hoc analysis. Most of the significant changes were observed during *dhyana*. These were an increase in the finger plethysmogram amplitude, a decrease in heart rate, breath rate, and changes in both the frequency and time domain analyses of the heart rate variability (HRV) (Indian Council of Medical Research Project Report, 2009). Frequency domain analysis of the HRV resulted in a significant decrease in low frequency (LF) power, an increase in high frequency (HF) power, and decrease in the LF/HF ratio during *dhyana*.

Time domain analysis of the HRV resulted in an increase in the NN50 count and the pNN50 during *dhyana*. During *dharana* there was a significant increase in the skin resistance level, with no other change during the practice. During *ekagrata* there was a significant increase in the skin resistance level, LF power, and a decrease in the HF power of the HRV. During *cancalata* the skin resistance level increased, as did the breath rate and LF power of the HRV.

In all four sessions there was an increase in the skin resistance level. However, apart from this, the changes during *ekagrata* and *cancalata* suggested increased sympathetic activity, whereas all the changes seen in *dhyana* were suggestive of reduced sympathetic activity and a shift towards vagal dominance. The decrease in the breath rate during *dhyana* is in keeping with this state being associated with increased relaxation.

Brainstem Auditory Evoked Potentials

Evoked potentials are used in meditation studies since the correlation between different evoked potential components and the underlying neural generators is fairly well worked out (Woods & Clayworth, 1985). Another reason is that the cerebral cortex is actively involved in meditation (Lazar et al., 2005). Hence cortico-efferent gating may occur with changes at subcortical relay centers (Napadow et al., 2008). Brainstem auditory evoked potentials (BAEPs) provide an objective physiological index of auditory functions subcortically. BAEPs were recorded with binaural click stimuli (of 50 μs duration, 40 Hz frequency, and 80 dB nHL intensity), averaged for 1,500 stimuli (Kumar, Nagendra, Manjunath, Naveen, & Telles, 2010).

The peak latency of a specific component, the wave V, increased significantly during *dharana*, *ekagrata*, and *cancalata* sessions, but there was no change during the practice of *dhyana*. An increase in the latency of an evoked potential component is understood to suggest that sensory information processing at the level of the underlying neural generator is delayed (Subramanya & Telles, 2009). Wave V is considered to correspond to the inferior colliculi, located in the tectum (midbrain) (McEvoy, Frumkin, & Harkins, 1980). The present results suggest that *dhyana* practice alone does not delay auditory sensory transmission at the brainstem level, whereas *dharana* practice is associated with a delay, as are the practices of *ekagrata* and *cancalata*.

Functional Magnetic Resonance Imaging

Functional magnetic resonance imaging (fMRI) measures hemodynamic changes related to neural activity in the brain or spinal cord (Deyoe, Bandettini, Neitz, Miller, & Winans, 1994). A 3.0 T scanner (Philips) was used to obtain echo-planar images (Indian Council of Medical Research Project Report, 2009; Dawn, Telles, George, & Naveen, 2010). For this experiment, participants switched among *cancalata*, *ekagrata*, *dharana*, and *dhyana* phases, spending one minute in each stage. The sequence was then repeated once more. All comparisons were made with respect to the *cancalata* phase, which was taken as the control phase.

During *ekagrata* there was bilateral activation of the middle temporal gyrus, (whose exact function is not known, but is believed to be connected with recognition of faces), contemplating distance related to spatial orientation, and accessing meanings of words during reading (Duara et al., 2008). The left parahippocampal gyrus activated in *ekagrata*, which is concerned with the formation of spatial memory. There was also bilateral fusiform gyri activation, which is correlated with face and body recognition, recognition of numbers and words, and abstraction of concepts (Thomaes et al., 2009). The bilateral activation of the cerebellum during *ekagrata* may suggest a certain level of involvement in regulation of tone and posture, which may be related to the fact that *ekagrata* is associated with paying greater attention (in this case) to the auditory information supplied.

Dharana is like *ekagrata*, a mental state characterized by increased attention. During *dharana* the increased activation of the anterior cingulate is suggestive of enhanced cognitive and attentional processing (Leroux et al., 2009). The bilateral activation of the dorsolateral prefrontal cortex suggests that *dharana* would facilitate functions known to be subserved by the prefrontal cortex, such as planning, cognitive behavior, and various functions, which come under the broad category of ''executive functions'' (Bertolino et al., 2009).

In *dhyana* (compared to *cancalata*) the changes were more complex. White matter hyperintensities were seen in the frontal region. White matter hyperintensities in the frontal region have been correlated with reduced frontal rCMRgle (regional glucose metabolism) and low executive scores (Tullberg et al., 2004). *Dhyana* was also associated with increased activation in the right orbitofrontal cortex, a region of the association cortex involved in cognitive processes such as decision making, as well as being involved in emotion regulation and reward.

Performance in a Letter Cancellation Task

The letter cancellation task assesses selective attention and concentration (Uttl & Pilkenton-Taylor, 2001). The performance in a six-letter cancellation task was assessed before and after each of the four practices separately (Kumar & Telles, 2009). There was also a control group of non-meditators, for comparison. All assessments were made before and after the practices. The net scores in the task were significantly higher after the *dharana* session and lower after the *cancalata* session. The results suggest that focusing on the symbol Om in *dharana* sessions may have a favorable effect on selective attention, concentration, visual scanning abilities, and a repetitive motor response, all of which are involved in a cancellation task. The absence of change after the *ekagrata* session suggests that non-meditative focusing did not have this effect.

Summary

Objective assessments of autonomic variables, brainstem auditory evoked potentials, functional magnetic resonance imaging, and performance in a cancellation task, showed differences between *dharana* and *dhyana* meditative sessions. The findings were mainly in keeping with the descriptions of these two meditative states mentioned in ancient yoga texts. It is also interesting to speculate that even if a particular meditation technique requires focusing (hence, resembling *dharana*), meditators may inadvertently enter the *dhyana* phase. Accordingly, differences observed in a group may occur because participants are in different stages (i.e., *dharana* or *dhyana*) of meditation. These observations suggest that knowing the descriptions of these practices in the ancient texts may help in understanding contemporary research findings.

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