EFFECT OF 'OM MEDITATION ON BRAINSTEM AUDITORY EVOKED POTENTIALS, AUTONOMIC AND RESPIRATORY VARIABLES' AND SELECTIVE ATTENTION

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ABSTRACT

Background

Research on meditation in volunteers who were previous naïve to meditation began with studies on transcendental meditation (TM) in the early 1970 (Wallace 1970, Wallace, et al. 1971). Subsequently, there have been several studies on widely differing meditation techniques and practitioners for e.g., study done by Hirai (1960) on Japanese Zazen meditation showed that during the practice, meditators showed an increase in heart rate and increase in beta activity in EEG. However, another study on Zen meditators showed that this meditation was associated with decrease in breath rate (Kasamatsu & Hirai 1966). Hence the two studies on Zen meditation showed different trends. The study by Hirai (1960) suggested that Zen meditation is activating which was in contrast to study done by Kamatsu and Hirai (1970), which suggested that Zen meditation is physiologically relaxing. Another study done on a meditation technique called Änanda Märga meditation (based on principles from täntric yoga text) showed that the practitioners of this meditation had an increase in heart rate from a mean of 69.4 to 72.8 and an increased skin conductance (Corby, et al. 1978). In contrast, a study by another group showed that Änanda Märga meditators had reduced breath rate (Elson, et al. 1977). Here again like the two studies on Zen meditation, two studies on Änanda Märga meditation also had conflicting implication. While the study by Corby et al (1978) and others suggested that Änanda Märga meditation is physiologically activating. The study by Elson et al (1970) suggested that Änanda Märga meditation decreased physiological activation. All these studies compared meditators with non-meditators. A different research design was attempted to assess whether

this would reduce inter-subject variability. This is a self-as-control design, which required the same person to be assessed in yoga session and in a non-yoga session (Telles, et al. 1992). This approach also involed assessing each yoga practitioners in repeated yoga and non-yoga sessions and it was found that there was definite inter-subject variability as well as intra-subject variability (i.e., where each pratitioners differed in their trends of results of different days).

Hence no clear picture emerged about the effect of meditation on autonomic and respiratory variables given the considerable intra and inter individual variability (Telles, & Desiraju, 1993a; Telles, & Desiraju, 1993b; Telles, et al. 1995; Telles, et al. 1998). Hence it was considered that practitioners may be showing different results because they practice meditation in different ways i.e., meditation on OM was found to be praticed by visualizing the syllable OM as it is written in Sanskrit while few other practitioners praticed by mentally repeating OM (Telles, et al. 1994). Thus an attempt was made to teach all practitioners to practice meditation in the same way and this resulted in group significant results (Telles, et al. 1994). However this may limit the individual's experience and sense of fulfillment derived from meditation.

This gave rise to the idea of examining description of meditation from traditional yoga texts may give, common results across different subjects. Hence, the present study intended to examine the effects of meditation as described in Pataïjali's yoga Sütras as well as two more mental states described in the Bhagavad Gétä. These mental states are Dhäraëä (Pataïjali's Yoga Sütras, Chapter 3: Verse 1) and Dhyäna (Pataïjali's Yoga Sütras, Chapter 3: Verse 2) and two other states, these are random thinking Caïcalatä (Bhagavad Gétä Chapter 6: Verse 34), and single pointed ekägratä (Bhagavad Gétä Chapter 6: Verse 12). In order to understand the psycholphysiological effects the assessments comprised an attenion task, autonomic and respiratory variables as well as brain stem auditory evoked potential. The last variable was selected to assess whether these practices influence sensory information processing as assessed by evoked potentials.

Aim

The present study aimed to assess the psycho-physiological changes during caïcalatä (random thinking), ekägratä (focusing), dhäraëä (meditative focusing), and dhyäna (meditation without focusing) on: (1) brainstem and auditory evoked potentials (2) autonomic and Respiratory variables (3) performance in a

six letter cancellation task.

Methods

Thirty subjects from Svämé Vivekänanda Yoga Research Foundation, Bangalore, South India were selected with ages ranging from 20 to 45 years (M = 29.1 ± SD = 6.5 years) who had a minimum of 6 months experience in 'OM' meditation.

Design

Each subject was assessed in four sessions i.e., two meditation (dhäraëä and dhyäna) and two control sessions (caïcalatä and ekägratä) to record brainstem auditory evoked potentials, autonomic and respiratory variables separately. And for performance in a cancellation task, assessments were made immediately before and after each session. The two control sessions were: (i) Ekägratä, i.e., single topic lecture and (ii) Caïcalatä, i.e., non-targeted thinking. The two meditation sessions were (i) Dhäraëä, i.e., focusing on the symbol 'OM' and (ii) Dhyäna, i.e., meditation with effortless focusing on OM, the object of meditation. All four sessions consisted of three states, i.e., 'pre' (5 minutes), 'during' (20 minutes), and 'post' (5 minutes).

The assessments were made on four different days, but at the same time of the day (i.e., the self-as-control design). The allocation of the subjects to the four sessions was randomized using a standard random number table. This was done to prevent the influence of being exposed to the laboratory for the first time, from influencing the results.

Assessments

I. BAEP were recorded using the Nicolet Bravo system (Nicolet Biomedicals, U.S.A.).

II. Autonomic and respiratory variables using 4-channel polygraph (Polyrite D, Recorders & Medicare Systems, Chandigarh, India)

a) Galvanic Skin Resistance (GSR)

b) Finger Plethysmogram Amplitude (FPA)

c) Electrocardiogram (EKG)

d) Respirogram

(i) Six letter cancellation task (SLCT)

Intervention

Throughout all sessions subjects kept their eyes closed and followed pre recorded instructions. The instructions emphasized carrying out the practice slowly, with awareness and relaxation. The meditators who participated in the study underwent a month of orientation sessions where they practiced two phases which formed a continuum in meditation (dhäraëä and dhyäna) as two separate sessions and two control sessions, i.e., caïcalatä or non-target thinking and ekägratä (by 'listening to a lecture on meditation, with multiple, yet associated thoughts').

These states are described in the traditional texts i.e., the Pataïjali's Yoga Sütras and Bhagavad Gétä, (Bhagavad Gétä Chapter 6: Verse 34, Chapter 6: Verse 12; Pataïjali's Yoga Sütras, Chapter 3: Verses 1-2) stating that when awake and in the absence of a specific task the mind is very distractible (caïcalatä), and has to be taken through the stages of 'streamlining the thoughts' (concentration or ekägratä), before moving on to the stage of meditation. These are: one-pointed concentration, non-analytical focusing or dhäraëä and a defocused, effortless single thought state or dhyäna.

During caïcalatä session (non-targeted thinking) the participants were directed to allow their thoughts to wander freely as they listened to a pre recorded general conversation of a local radio station transmission. During ekägratä practice participants were listening to a lecture on meditation. The dhäraëä session consisted of meditative focusing on the meaning of the Sanskrit syllable, 'OM', where OM is used as a symbol for the entire universe, representing that which sustains everything (Mäëòukya Upaniñat; Cinmayänanda, 1984). The dhyäna session consisted of meditation with effortless absorption with the object of meditation. For the two meditation sessions (dhäraëä and dhyäna) and the other two control sessions (caïcalatä & ekägratä) participants were given guided instructions with a compiled audio CD relevant to the respective sessions. All sessions (dhäraëä, dhyäna, caïcalatä, and ekägratä) constituted a practice of 20 minutes duration.

Data analysis

Statistical analysis was done for all variables using SPSS (Version 10.0). The peak latencies and peak amplitudes of all seven waves and all autonomic

variables were analyzed using repeated-measures analyses of variance (ANOVAs), and post-hoc analyses with Bonferroni adjustment was to compare 'pre' data with 'during' and 'post'. Also six letter cancellation task scores were analyzed using repeated-measures analyses of variance (ANOVAs), and post-hoc analyses with Bonferroni adjustment was to compare 'pre' with 'post' scores.

The repeated measures analyses of variance (ANOVAs) were performed with two 'Within Subjects' factors, i.e., Factor 1: Sessions; with four levels, viz., caïcalatä, ekägratä, dhäraëä, and dhyäna, and Factor 2: States; with six levels, viz., Pre, During (D1 to D4), and Post. These repeated measures ANOVAs were carried out for the peak latency and peak amplitude of all levels as well as autonomic and respiratory variables. For letter cancellation task the repeated measures analyses of variance (ANOVAs) were performed with two 'Within subjects' factors, i.e., Factor 1: Sessions; with four levels, viz., caïcalatä, ekägratä, dhäraëä, and dhyäna, and Factor 2: States; with two levels Pre and post. This was followed by a post-hoc analysis with Bonferroni adjustment for multiple comparisons between the mean values of different states (Pre, During 1 to During 4 and Post) and pre and post data analysis was done for letter cancellation task.

Results and Discussion

(i). Brainstem auditory evoked potential –There was a significant increase in the latency of Wave V during the caïcalatä session (Pre versus During), ekägratä session (Pre versus During & post) and following the dhäraëä session (Pre versus Post).

Hence irrespective of whether meditators were in a state of random thinking (caïcalatä) or channelized thought in concentration (ekägratä) there was a delay in sensory information processing, as mentioned above at the mid-brain, (possibly the inferior colliculus) level. The mental state was characterized by a lack of effort during dhyäna session, where as there was effort involved during dhäraëä session; in both the sessions, the latency of wave V did not show any significant delay in sensory information processing. In contrast, there was a significant delay seen post dhäraëä session while no such changes was observed post dhyäna session.

ii) Autonomic and respiratory variables-

• Galvanic Skin Resistance (GSR): There was a significant increase in the galvanic skin resistance during and after the dhyäna session in comparison to caïcalatä, ekägratä, and dhäraëä sessions.
• Finger Plethysmogram Amplitude (FPA): There was a significant increase in the digit pulse volume in dhyäna session (pre versus during).
• Electrocardiogram (EKG): There was a significant decrease in the heart rate in dhyäna session (pre versus during & post).
• Respiratory rate: There was a significant increase in the respiratory rate in caïcalatä sessions (pre versus during & post). But in session dhyäna there was significant decrease in respiratory rate (pre versus during & post).
• HRV LF: There was a significant increase in low frequency in caïcalatä and ekägratä sessions (caïcalatä (pre versus during & post), ekägratä (pre versus during & post). But there was significant decrease in low frequency in dhyäna session (pre versus during & post).
• HF: There was a significant decrease in high frequency in ekägratä session (pre versus during & post), while there was significant increase in high frequency in dhyäna session (pre versus during & post).
• LF/HF: There was a significant increase in low and high frequency ratio in ekägratä session (pre versus during & post).
In the present study the LF power was higher during caïcalatä, ekägratä and lower in dhyäna sessions. The HF power was lower during the ekägratä practice and higher during the dhyäna practice. The LF/HF ratio was higher during the ekägratä practice. The changes in LF and HF power suggest that there was a shift towards the increased sympathetic activity during caïcalatä and ekägratä, where as increased parasympathetic activity was observed during dhyäna sessions. Hence dhäraëä did not influence the HRV.
In the present study there was a significantly higher increase in skin resistance during dhyäna session in compare to other sessions. The rate of breathing is known to vary directly with the level of anxiety (Srinivas & Telles, 1999). A decreased breath rate is a well recognized correlate of reduced psychophysiological arousal. Hence for this variable also there were difference between dhäraëä and dhyäna. The heart rate was also lower during dhyäna in the present study there was a lowering of both breathing rate and heart rate during dhyäna suggestive of physiological relaxation.

• Six letter cancellation task (SLCT): Total and net scores were significantly higher after the dhäraëä session compared to the pre scores, whereas after the caïcalatä session they were significantly lower. No significant change was observed in other sessions for the letter cancellation task.

Conclusions

These results showed that information transmission along the auditory pathway is delayed during caïcalatä and ekägratä with no change during dhäraëä and dhyäna.

In dhyäna there was a relative increase in wave V amplitude (relative to wave III) suggesting recruitment of more neurons at the inferior collicular level compared to before. This suggests that during dhyäna auditory information transmission was delayed at the inferior collicular level (the tectum) as the wave V corresponds to the tectum. Also the autonomic and respiratory variables suggested a higher magnitude of psycho-physiological relaxation during dhyäna as compared to other sessions. Performance in the six letter cancellation task also suggested that meditative focusing (dhäraëä) may improve attention.

SUMMARY OF THE FINDINGS

1. In the present study thirty subjects were studied in four separate sessions i.e., caïcalatä (random thought), ekägrata (concentration), dhäraëä (focused attention) and dhyäna (meditation). The sample size was calculated and the effect size obtained, based on reports in an unpublished Ph.D thesis entitled 'Psychophysiology of meditation including responses to external stimuli' (Naveen, 2005).

2. In the traditional texts [the Pataïjali's Yoga Sütras (Taimini, 1961) and Bhägavad Gétä (Bhakttivedänta Svämi Prabhupäda, 1998)] it has been described that when awake and in the absence of a specific task the mind is very distractible (caïcalatä), and has to be taken through the stages of 'streamlining the thoughts' (concentration or ekägratä), followed by one-pointed concentration (focusing or dhäraëä), then reaching the meditative state (defocused, effortless single thought state or dhyäna). Earlier findings suggest that 'OM' meditation facilitates the neural activity in mesencephalic or

diencephalic level as well as psycho-physiological relaxation. Based on these backgrounds, the present study was carried out to understand the psycho-physiological effects of these four states of wakeful mind.
3. The study design consisted of four sessions i.e., two meditation and two control sessions. All four sessions consisted of three states, i.e., 'pre' (5 minutes), 'during' (20 minutes), and 'post' (5 minutes) separately on different days.

4. The following assessments were made:
• Brainstem Auditory Evoked Potentials (BAEPs)
• Autonomic and Respiratory variables (ARV) and
• Six letter cancellation task (SLCT)
5. For each of the variables the data were analyzed separately using repeated measures ANOVA followed by post-hoc analysis.
6. The results have shown the following changes:
(i) Brainstem auditory evoked potential –There was a significant increase in the latency only of Wave V during the caïcalatä session (Pre versus During, 0.4%), ekägratä session (Pre versus During & post, 0.9% and 1.56%) and following the dhäraëä session (Pre versus Post, 1.22%). There were no significant changes in amplitude of wave V as well as other waves during all sessions.
(ii) Autonomic and respiratory variables
Galvanic Skin Resistance (GSR): There was a significant increase in the galvanic skin resistance during and after the dhyäna session (8.60% to 17.03%) in comparison to caïcalatä (7.3% to 10.28%), ekägratä (7.43% to 11.36%), and dhäraëä (5.20% to 11.36%) sessions.
• Finger Plethysmogram Amplitude (FPA): There was a significant increase in the digit pulse volume in dhyäna session (Pre versus During 2.28% to 12.26%).
• Electrocardiogram (EKG): There was a significant decrease in the heart rate in dhyäna session (Pre versus During & post, 4.93% to 7.73%).
• Respiratory rate: There was a significant increase in the respiratory rate in caïcalatä sessions (Pre versus During & post 2.69% to 15.56%). But in session dhyäna there was significant decrease in respiratory rate (Pre versus During & post 8.86% to 19.59%).
• HRV LF: There was a significant increase in low frequency in caïcalatä and ekägratä sessions caïcalatä (Pre versus During & post 15.95% to 22.67%), ekägratä (Pre versus During & post 13.22% to 15.78%). But there was significant decrease in low frequency in dhyäna session (Pre versus During & post 15.42% to 25.53%).

• HF: There was a significant decrease in high frequency in ekägratä session (Pre versus During & post 16.15% to 19.23%), while there was significant increase in high frequency in dhyäna session (Pre versus During & post 23.55% to 37.76%).
• LF/HF: There was a significant increase in low and high frequency ratio in ekägratä session (Pre versus During & post 41.44% to 83.67%).
(iii) Six letter cancellation task (SLCT): Total and net scores were significantly higher after the dhäraëä session (16.21% and 13.31%) compared to the pre scores, whereas after the caïcalatä session they were significantly lower (24.65% and 23.28%). No significant change was observed in other sessions for the letter cancellation task.
7. The possibility that the neural transmission of auditory sensory information is not delayed through the inferior colliculus during dhyäna may be considered to be supported by the fact the wave V to wave III (wave V / wave III) amplitude ratio was significantly higher during dhyäna. LF power was lower during dhyäna sessions. The HF power was higher during the dhyäna practice. This may be due to relaxation component of dhyäna. An increased skin resistance is well recognized as marker of reduced psychophysiological arousal in meditation (Orme-Johnson, 1973). It is also to be noted that the highest 13 percent increase was during dhyäna. Unlike these variables it is well established that the breath rate depends upon numerous factors ranging from physical activity to psychological stressors (Stevenson and Ripley, 1952). The heart rate was also lower during dhyäna in the present study there was a lowering of both breathing rate and heart rate during dhyäna suggestive of physiological relaxation. The RMSSD (along with the pNN50) are time domain measures which are highly correlated with frequency domain measures and recognized to be strongly dependent on vagal tone (Massin et al., 1999). Hence ekägratä, dhäraëä and dhyäna appeared to be related to changes in vagal tone, the present results suggest that meditative focusing (dhäraëä) may be the phase during which attention improves

CONCLUSIONS

These results showed that information transmission along the auditory pathway is delayed during caïcalatä and ekägratä with no change during dhäraëä and dhyäna. In dhyäna there was a relative increase in wave V amplitude (relative to wave III) suggesting recruitment of more neurons at the inferior collicular level durig compared to before. This suggests that auditory information transmission was delayed at the inferior collicular level (the

tectum) as the wave V corresponds to the tectum. Also, the changes in autonomic and respiratory variables suggested a higher magnitude of psycho-physiological relaxation during dhyäna (decrease by 18% in RR, 6% in HR whereas increase by 10% in PLT, and 13% in GSR) as compared to other sessions. Performance in the six letter cancellation task also suggested that meditative focusing (dhäraëä) may improve attention by 13% in net score. Hence the null Hypothesis: (1) the information transmission in auditory pathway will not be delayed in caïcalatä, ekägratä, and dhäraëä while it will not remain unaltered if not delayed at the brainstem level in dhyäna phase (2) dhyäna would not induce a state of deep rest with alertness and there will be no autonomic arousal in other phases of ekägratä and dhäraëä (3) there will be no increased attention in all phases ekägratä, dhäraëä and dhyäna with no higher increase in dhyäna is disproved. It appears that separating meditation as dhäraëä and dhyäna and comparing these phases with caïcalatä, and with ekägratä as a third, meditative state is useful. The states have different and distinct changes.

Reference

• Adiswarananda, Svämé. (2004). Meditation and its Practices. Adaita Asharama: Kolkata.
• Agarwal, A. K., Kalra, R., Natu, M. V., Dadich, A. P., & Deswal, R. S. (2002). Psychomotor performance of psychiatric inpatients under therapy: assessment by paper and pencil tests. Human psychopharmacology, 17, 91-93.
• Amador-Campos, j. A., & Kirchner-Nebot, T. (1999). Correlations among scores on measures of field dependence-independence cognitive style, cognitive ability, and sustained attention. Perceptual and Motor Skills, 88, 236-239.
• Apte, S. V. (1992). Practical Sanskrit English Dictionary. Motilal Banarasidas Publishers, Pvt. Ltd: Delhi.
• Atreya, B. L., & Samvid. (1993). The Vision and way of Vaçiñöha. Indian Heritage Trust: Madras.
• AARC Clinical Practice Guidelines for metabolic measurement using indirect calorimetry during mechanical ventilation. Respiratory Care. 1994; 39 (12): 1170-1175.
• Akishige Y, A historical survey of the psychological studies in Zen. Kyushu psychological studies, V, Bulletin of the faculty of Literature of Kyushu University. 1968; 11: 1-56.
• Altman, D. G., Gore, S. M., Gardner, M. J., & Pocock, S. J. (1983). Statistical

guidelines for contributors to medical journals. British Medical Journal, 286: 1489-1493.
• Bahadur, K. P. (1988). The wisdom of Çaìkhya. Sterling Pvt. Ltd: Bangalore.
• Bangali, B. (2002). Yoga Sütra of Pataïjali with the commentary of Vyasa. Motilal Banarasidas Publishers Pvt. Ltd: Delhi.
• Banquet, J. P. (1973). Spectral analysis of the EEG in meditation. Electroencephalography and clinical neurophysiology, 35, 143-151.
• Bhaktivedanta Svämé Prabhupada, A. C. (1998). Bhagavad Gétä: as it is. The Bhaktivedanta Book Trust: Mumbai.
• Brefczynski-Lewis, J. A., Lutz, A., Schaefer, H. S., Levinson, D. B., & Davidson, R. J. (2007). Neural correlates of attentional expertise in long-term meditation practitioners. Proceedings of the National Academy of Sciences of the United States of America, 104(27), 11483-11488.
• Brown, D. P. (1977). A model for the levels of concentrative meditation. The International journal of clinical and experimental hypnosis, 25, 236-273.
• Bernardi, L., Sleight, P., Bandinelli, G., Cencetti, S., Fattorini, L., Johanna Wdowczyc Szulc, J. & Lagi, A. (2001). Effect of rosary prayer and yoga mantras on autonomic cardiovascular rhythms: comparative study. British medical journal, 323: 22-29.
• Barnes, V. A., Treiber, F. A., & Davis, H. (2001). Impact of Transcendental Meditation on cardiovascular function at rest and during acute stress in adolescents with high normal blood pressure. Journal of psychosomatic research, 51(4): 597-605.
• Berntson, G. G., Norman, G. J., Hawkley, L. C., & Cacioppo, J. T. (2008). Spirituality and Autonomic Cardiac Control. Annals of behavioral medicine, 35(2): 198–208.
• Becker, D. E., Shapiro, D. (1981). Physiological response to clicks during Zen, Yoga, and TM meditation. Psychophysiology, 18: 694 -699.
• Brahmavadhut, Sri Sukhanandanatha. (1992). Shabdarthachintamani. Printwell: Jaipur.
• Brunia, C. H. M. (1993). Waiting in readiness: gating in attention and motor preparation. Psychophysiology, 30: 327-339.
• Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. Psychological bulletin, 132, 180-211.
• Chan, D., & Woollacott, M. (2007). Effects of Level of Meditation Experience on Attentional Focus: Is the Efficiency of Executive or Orientation Networks Improved? Journal of alternative and complementary medicine, 13, 651-658.

• Cahn, B. R., & Polich, J. (2009). Meditation (Vipassana) and the P3a event-related brain potential. International journal of psychophysiology, 72(1): 51-60.
• Chao, Khun, Phra Sobhana Dhammasudhi. (1968). Insight Meditation. The Committee for the advancement of Buddhism: London.
• Cinmayänanda, Svämé. (2001). Kenopanisad. Central Cinmayänanda Mission: Bombay.
• Cinmayänanda, Svämé. (2002). Kaöha Upanisad. Central Chinmayananda Misión: Bombay.
• Cinmayänanda, Svämé. (2002). Talks on Shanakar's Vivekcudmani. Central Cinmayänanda Misión: Bombay.
• Cinmayänanda, S. (1984). Mandukya Upanisad. Sachin publishers: Bombay.
• Cinmayänanda, Svämé. (2001). The Holy Gétä. Central Chinmaya Mission Trust: Mumbai.
• Cinmayänanda, Svämé. (2002). Talks on Shanakar's Vivekcudmani. Central Cinmayänanda Mission, Bombay.
• Corby, J. C., Roth, W. T., Zarcone, V. P. J. R., & Kopell, B. S. (1978). Psychophysiological correlates of the practice of Tantric Yoga meditation. Archives of General Psychiatry, 35, 571-577.
• Cysarz, D. (2005). Büssing A. Cardiorespiratory synchronization during Zen meditation. European journal of applied physiology, 95(1): 88-95.
• Cranson, R., Goddard, P. H., & Orme-Johnson, D. (1990). P300 under conditions of temporal uncertainty and filter attenuation: Reduced latency in long-term practitioners of TM. Psychophysiology, 27: S23.
• David, w. (1973). Orme-johnson Autonomic Stability and Transcendental Meditation. Psychosomatic Medicine, 35: 341-349.
• Doraiswamy, P. M., & Xiong, G. L. (2007). Does Meditation Enhance Cognition and Brain Longevity? Ann N Y Acad Sci. [Epub ahead of print]
• Delbanco, T. (1993). The healing roles of doctor and patient, in Healing and the mind, B. Moyers, New York, ed., David Grubin Productions, 7-23.
• Deiber, M. P., Ibañez, V., Fischer, C., Perrin, F., & Mauguiére, F. (1988). Sequential mapping favors the hypothesis of distinct generators for Na and Pa middle latency auditory evoked potentials. Electroencephalography and Clinical Neurophysiology, 71: 187-197.
• Dillbeck, M. C. (1977). The effect of the Transcendental Meditation technique on anxiety level. Journal Clinical Psychology, 33(4): 1076-1078.
• Elson, B. D., Hauri, P., & Cunis, D. (1977). Physiological changes in Yoga meditation. Psychophysiology, 14, 52-57.

• Feuerstein, G. (2001). The Yoga tradition, its history, litrature, philosophy and practice. Hohm Press: Arizona.
• Fredrikson, M., & Engel, B. T. (1985). Cardiovascular and electrodermal adjustments during a vigilance task in patients with borderline and established hypertention. Journal of psychosomatic research, 29, 235-246.
• Fox, E. (1993). Attentional bias in anxiety: selective or not?. Behavioral Research and Therapy, 31(5): 487-93.
• Gamabhiranada, Svämé. (1986). Çvetäçvatara Upaniñat with the comentary of Shankarachanrya. Advaita Ashram: Calcutta.
• Gamabhiranada, Svämé. (1995). Muëòaka upaniñat. Advaita Ashram: Calcutta.
• Gamabhiranada, Svämé. (1998). Öaittiréya upaniñat. Advaita Ashram: Calcutta.
• Gordeev, S. A., Baziian, B. Kh., Liubimov, N. N. (1992). The dynamics of somatosensory and visual evoked potentials as a correlate of reversible states of altered consciousness. Biulleten' eksperimental'noĭ biologii i meditsiny, 114(11): 451-453.
• Goyeche, J. R. M., Chihara, T., & Shimizu, H. (1972). Two concentration methods: A preliminary comparison. Psychologia, 15: 110-111.
• Gujjar, A. R., Sathyaprabha, T. N., Nagaraja, D., Thennarasu, K., & Pradhan, N. (2004). Heart rate variability and outcome in acute severe strok: role of power spectral analysis. Neurocritical care, 1(3): 347-353.
• Hirai, T. (1960). Electroencephalographic study on the Zen Meditation (ZAZEN)-EEG changes during concentrated relaxation. Psychiatria et neurologia Japonica, 62, 76-105.
• Hamada, T., Murata, T., Takahashi, T., Ohtake, Y., Saitoh, M., Kimura, H., Wada, Y., & Yoshida, H. (2006). Changes in autonomic function and EEG power during mental arithmetic task and their mutual relationship. Rinsho byori. The Japanese journal of clinical pathology, 54(4): 329-334.
• Hirai, T. (1975). Zen Meditation Therapy. Japan publications, Tokyo.
• Jasper, H. H. (1958). The ten-twenty electrode system of the International federation. Electroencephalography and clinical neurophysiology, 10: 371-375.
• Joseph, C., Ram, Shankar, A., Kulkarni, D. D., Ramchandra, M., Narasimhalu, G., & Desiraju, T. (1987). Post meditational effects of Brahmakumaris (BK) and Transcendental Meditation(TM) on computer – averaged event related evoked potential components recorded in the P300 cognitive paradigm. Indian Journal of Physiology and Pharmacology. 31: 49.

• Kubota, Y., Sato, W., Toichi, M., Murai, T., Okada, T., Hayashi, A., & Sengoku A. (2001). Frontal midline theta rhythm is correlated with cardiac autonomic activities during the performance of an attention demanding meditation procedure. Brain research. Cognitive brain research, 11, 281-287.
• Kasamatsu, A., Hirai, T. (1966). An electroencephalographic study on the Zen meditation (zazen). Folio psychiatry Neurology Japonica, 20: 315-36.
• Khushu, S., Telles, S., Kumaran, S., Naveen, K. V. & Tripathi, R. P. (2000). Frontal activation during meditation based on functional magnetic resonance imaging (fMRI). Indian Journal of Physiology and Pharmacology, 44(5): 34.
• Kjaer, T. W., Bertelsen, C., Piccini, P., Brooks, D., Alving, J., & Lou, H. C. (2002). Increased dopamine tone during meditation-induced change of consciousness. Brain Research. Cognitive Brain Research, 13(2): 255-259.
• Lang, R., Dehof, K., Meurer, K. A., & Kaufmann, W. (1979). Sympathetic activity and Transcendental meditation. Journal of neural transmission, 44, 117-135.
• Lauter, J. L., Oyler, R. F., & Lord-Maes, J. (1993). Amplitude stability of auditory brainstem responses in two groups of children compared with adults. British journal of audiology, 27: 263-271.
• Lazar, S. W., Kerr, C. E., Wasserman, R. H., Gray, J. R., Greve, D. N., Treadway, M. T., McGarvey, M., Quinn, B. T, Dusek, J. A, Benson, H., Rauch, S. L., Moore, C. I., & Fischl B. (2005). Meditation experience is associated with increased cortical thickness. Neuroreport, 28: 1893-1897.
• Lutz, A., Greischar, L. L., Perlman, D. M., & Davidson, R. J. (2009). BOLD signal in insula is differentially related to cardiac function during compassion meditation in experts vs. novices. Neuroimage. [Epub ahead of print]
• Laberge, D. (1995). Attentional processing: the brain's art of mindfulness. UK: Harvard University Press, Cambridge.
• Lehrer, P. M., Schoicket, S., Carrington, P., & Woolfolk, R. L. (1980). Psychophysiological and cognitive responses to stressful stimuli in subjects practicing progressive relaxation and clinically standardized meditation. Behavior Research and Therapy, 18(4): 293-303.
• Lou, H. C., Kjaer, T. W., Friberg, L., Wildschiodtz, G., Holm, S., & Nowak, M. A. (1999). A 150 – H20 PET study of meditation and the resting state of normal consciousness. Human Brain Mapping, 7(2): 98-105.
• Madhusudhan, Saraswati., & Gambhiranada, Svämé. (1998). Bhagavad Gétä. Advaita Ashrama, Himalaya.
• Manjunath, N. K., Srinivasa, R., Nirmala, K. S., Nagendra, H. R., Kumar, A., &

Telles, S. (1998). Shorter latencies of middle latency auditory evoked potentials in congenitally blind compared to normal sighted subjects. The International journal of neuroscience, 95: 173-181.
• McEvoy, T. M., Frumkin, L. R, Harkins, S. W. (1980). Effects of meditation on brainstem auditory evoked potentials. The International journal of neuroscience, 10: 165-170.
• Mishra, U. K., & Kalita, J. (2001). Clinical neurophysiology. B. I. Churchill Livingstore: New Delhi.
• Mokshadananda, Svämé. (1997). Jivan-Mukti-Viveka of Svämé Vidyaranya. Advaita Ashrama: Calcutta.
• Muktibodhananada, Svämé. (2003) HaöhaYoga Paradipika. Yoga Publication Trust: Munger.
• Mumukshananda, Svämé. (1998). Teachings of Ramakrishna Pramahansa. Advaita Ashram: Champawat, Himalaya.
• Murata, T., Takahashi, T., Hamada, T., Omori, M., Kosaka, H., Yoshida, H., & Wada, Y. (2004). Individual trait anxiety levels characterizing the properties of Zen meditation. Neuropsychobiology, 50, 189-194.
• Malliani, A., Pagani, M., Lombardi, F., & Cerutti, S. (1991). Cardiovascular neural regulation explore in the frequency domain, Circulation, 84: 482-92.
• Mountcastle, V. B. (1980). Medical Physiology (vol.2). St. Louis: CV Mosby; 1980.
• Nagendra, H. R. (2001). Mind Sound Resonance Technique. Svämé Vivekananda Yoga Prakashana: Bangalore.
• Nagendra, H. R., & Nagrathana, R. (2003). New perspectives in stress management. Svämé Vivekananda Yoga Prakashana: Bangalore.
• Nagendra, H. R., & Nagrathana, R. (2001). Promotion of Positive Health. Svämé Vivekananda Yoga Prakashana: Bangalore.
• Nagendra, H. R., Svämé, N. V. C., & Mohan, T. (2003). Pataïjali Yoga Sütras. Svämé Vivekananda Yoga Prakashana: Bangalore.
• Napadow, V., Dhond, R., Conti, G., Makris, N., Brown E. N., & Barbieri, R. (2008). Brain correlates of autonomic modulation: combining heart rate variability with fMRI. Neuroimage, 42: 169-177.
• Natu, M. V., & Agarwal, A. K. (1997). Testing of stimulant effects of coffee on the psychomotor performance: an exercise in clinical pharmacology. Indian journal of pharmacology, 29, 11-14.
• Newberg, A., Alavi, A., Baime, M., Pourdehnad, M., Santanna, J., & D'aquili, E. (2001). The measurement of regional cerebral blood flow during the complex

cognitive task of meditation: a preliminary SPECT study. Psychiatry research, 10, 113-122.
• Naveen, K. V., & Telles, S. (2003). Sensory perception during sleep and meditation: common features and differences. Perceptual and Motor Skills, 96: 810-11.
• Nishimura. M., & Onodera, S. (2000). [Relaxative effects of supine floating on heart rate, blood pressure and cardiac autonomic nervous [correction of nerveous system activity] Uchu Koku Kankyo Igaku, 37(3): 49-56
• Niskanen, J. P., Tarvainen, M. P., Ranta-aho, P. O., & Karjalainen, P. A. (2004). Software for advanced HRV analysis. Computer Methods and Programs in Biomedicine, 76: 73-81.
• Narayansvami, K. A. (2003).Thirty minor Upaniñads. Himanshu Laser System: Delhi.
• Orme-Johnson, D. W. (1973). Autonomic stability and Transcendental Meditation. Psychosomatic medicine, 35, 341-349.
• Orme-Johnsona, D. W., Schneidera, R. H., Sonb, Y. D., Nidicha, S., & Cho, Z. H. (2006). Neuroimaging of meditation's effect on brain reactivity to pain. Neuroreport, 21, 17(12): 1359–1363.
• Polich, J. (1999). P300 in clinical applications. In E. Niedermeyer, F. Lopes da Silva, (Eds.), Electroencephalography: Basic Principles, Clinical Applications and Related Fields (pp. 1073-1091). Baltimore-Munich: Urban and Schwarzenberg.
• Panjwani, U., Selvamurthy, W., Singh S. H., Mukhopadhyay, S., Thakur, L. (2000). Effect of Sahaja yoga meditation on auditory evoked potentials (AEP) and visual contrast sensitivity (VCS) in epileptics. Applied psychophysiology and biofeedback, 25 (1): 1-12.
• Peng, C. K., Henry, I. C., Mietus, J. E., Hausdorff, J. M, Khalsa, G., Benson, H., & Goldberger, A. L. (2004). Heart rate dynamics during three forms of meditation. International journal of cardiology, 95(1): 19-27.
• Paul-Labrador, M., Polk, D., Dwyer, J. H., Velasquez, I., Nidich, S., Rainforth, M., Schneider, R., & Merz, C. N. (2006). Effects of a randomized controlled trial of transcendental meditation on components of the metabolic syndrome in subjects with coronary heart disease. Archives of internal medicine, 166(11): 1218-1224.
• Phongsuphap, S., Pongsupap, Y., Chandanamattha, P., & Lursinsap C. (2007). Changes in heart rate variability during concentration meditation. International journal of cardiology, 130(3): 481-484.
• Peressutti, C., Martín-González, J. M., García-Manso, M. J., & Mesa, D. (2009).

Heart rate dynamics in different levels of Zen meditation. International journal of cardiology, [In press].
• Polich, J. (2004). Clinical application of P300 event-related brain potential. Physical Medicine and Rehabilitation Clinics of North America, 15, 133-161.
• Prabhavananda, Svämé. (2002). Pataïjali Yoga Sütras. Sri Ramakrishana Math, Madras.
• Prasad, P. S. K. (1990). Bhagavad Gétä Explained to the Modern Man. Karunkar Pandarangi, Hyderabad.
• Pandit Usharbudh Arya. (1986). Yoga Sütras of Pataïjali with the exposition of Vyasa. The Himalayan International Institute: Pennsylvania.
• Ramgopalachari, C. (1958). Mahäbharata. Bharti Vidya Bhavan: Bombay.
• Rai, L., & Ram, K. (1993). Energy expenditure and ventilatory responses during virasana- a yogic standing posture. Indian Journal of Physiology and Pharmacology, 37(1), 45-50.
• Rai, L., Ram, K., Kant, U., Madan, S. K., & Sharma, S. K. (1994). Energy expenditure and ventilatory responses during siddhasana - a yogic seated posture. Indian Journal of Physiology and Pharmacology, 38(1), 29-33.
• Raghuraj, P., Ramakrishnan, A. G., Nagendra, H. R. & Telles, S. (1998). Effect of two selected yogic-breathing techniques on heart rate variability. Indian Journal of Physiology and Pharmacology, 42(4): 467-472.
• Rinck, M., Becker, E. S., Kellermann, J., & Roth, W. T. (2003). Selective attention in anxiety: distraction and enhancement in visual search. Depression and Anxiety, 18(1): 18-28.
• Rinck, M., Becker, E. S., Kellermann, J., & Roth, W. T. (2003). Selective attention in anxiety: distraction and enhancement in visual search. Depression and Anxiety, 18(1): 18-28.
• Sarang, S. P., & Telles, S. (2006a) Oxygen consumption and respiration during and after two yoga relaxation techniques. Applied psychophysiology and biofeedback, 31, 143-153.
• Sarang, P., & Telles, S. (2006b) Effects of two yoga based relaxation techniques on heart rate variability. International journal of stress management, 13, 460-475.
• Sarang, S. P., & Telles, S. (2006c) Changes in P300 following two yoga-based relaxation techniques. The International journal of neuroscience, 116, 1419-1430.
• Sarang, S. P., & Telles, S. (2007). Immediate effect of two yoga-based relaxation techniques on performance in a letter-cancellation task. Perceptual

and Motor Skills, 105, 379-385.
• Srinivasan, N., & Baijal, S. (2007). Concentrative meditation enhances preattentive processing: a mismatch negativity study. Neuroreport, 18(16): 1709-1712.
• Subramanya, P., & Telles, S. (2009). Changes in midlatency auditory evoked potentials following two yoga-based relaxation techniques. Clinical EEG and neuroscience, 40(3): 190-195.
• Solberg, E. E., Ekeberg, O., Holen, A., Ingjer, F., Sandvik, L., Standal, P. A., & Vikman, A. (2004). Hemodynamic changes during long meditation. Applied psychophysiology and biofeedback, 29(3): 213-221.
• Satyananda, Saraswati, Svämé. (1992). Meditations. Bihar School of Yoga: Munger.
• Sugi, Y., & Akutsu, K. (1968). Studies on respiration and energy-metabolism during sitting in Zazen, Research Journal of Physical Education, 12, 190-206.
• Sukhanandanatha, Brahmavadhut. (1992). Sri. Shabdarthachintamani. Printwell, Jaipur.
• Sun, F. L., Li, D. M, & Li, G. Y. (1996). Influence of different combination of mental activity and respiratory cycle on heart rate variability. Zhongguo Zhong Xi Yi Jie He Za Zhi, 16(3): 153-155.
• Swahanada, Svämé. (1984). Chändogya upaniñat. Sri Ramkrishana Math, Madras.
• Szabo, A., Mesko, A., Caputo, A., & Gill, E. T. (1999). Examination of exercise-induced feeling states in four modes of exercise. International Journal of Sport Psychology, 29: 376-379.
• Sakakibara, M., Takwuchi, S., & Hayano, J. (1994). Effect of relaxation training on cardiac parasympathetic tone. Psychophysiology, 31: 223-228.
• Taimini, I. K. (1986). Science of Yoga. The Theosophical Society Publishing House, Madras.
• Takahashi, T., Murata, T., Hamada, T., Omori, M., Kosaka, H., Kikuchi, M., Yoshida, H., & Wada, Y. (2005). Changes in EEG and autonomic nervous activity during meditation and their association with personality traits. International journal of psychophysiology, 55(2): 199-207.
• Tapasyananda, Svämé. (2002). Srimad Bhavad Gétä. Sri Ramkrishana Math, Chennai.
• Tapasyananda, Svämé. (1982). Çrémad Bhägavat Mahäpuräëa. Sri Ramkrishana Math: Chennai.
• Telles, S., & Desiraju, T. (1993). Recording of auditory middle latency evoked

potentials during the practice of meditation with the syllable ‘OM’. The Indian journal of medical research, 98: 237-239.
• Telles, S., Nagarathna, R., & Nagendra, H. R. (1994). Alterations in auditory middle latency evoked potentials during meditation on a meaningful symbol "OM". The International journal of neuroscience, 76: 87-93.
• Telles, S., Nagarathna, R., & Nagendra, H. R. (1995). Autonomic changes during ‘OM’ meditation. Indian journal of physiology and pharmacology, 39(4): 418-420.
• Telles, S., Nagarathna, R., & Nagendra, H. R. (1998). Autonomic changes while mentally repeating two syllables – one meaningful and the other neutral. Indian journal of physiology and pharmacology, 42(1): 57-63.
• Telles, S., & Naveen, K. V. (2004). Changes in middle latency auditory evoked potentials during meditation. Psychological reports, 94: 398-400.
• Telles, S., & Desiraju, T. (1993b). Autonomic changes in Brahmakumaris raja yoga meditation. International journal of psychophysiology, 15, 147-152.
• Telles, S., Raghuraj, P., Maharana, S., Nagendra, H. R. (2007). Immediate effect of three yoga breathing techniques on performance on a letter-cancellation task. Perceptual and motor skills, 104, 1289-1296.
• Telles, S., Reddy, S. K., & Nagendra, H. R. (2000). Oxygen consumption and respiration following two yoga relaxation techniques. Applied psychophysiology and biofeedback, 25, 221-227.
• Travis, F., Tecce, J., Arenander, A., & Wallace, R. K. (2002). Patterns of EEG coherence, power, and contingent negative variation characterize the integration of transcendental and waking states. Biological Psychology, 61, 293-319.
• Tang, Y. Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q., Yu, Q., Sui, D., Rothbart, M. K., Fan, M., & Posner, M. I. (2007). Short-term meditation training improves attention and edings of the National Academy of Sciences of the United States of America, 104(43): 17152-17156.
• Tang, Y. Y., Ma, Y., Fan, Y., Feng, H., Wang, J., Feng, S., Lu, Q., Hu, B., Lin, Y., Li, J., Zhang, Y., Wang, Y., Zhou, L., & Fan, M. (2009). Central and autonomic nervous system interaction is altered by short-term meditation. Proceedings of the National Academy of Sciences of the United States of America, 106(22): 8865-8870.
• Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. (1996). Heart Rate Variability: standards of measurement, physiological interpretation, and clinical use.

European Heart Journal, 17: 354-81.
• Telles, S., Joshi, M., Dash, M., Raghuraj, P., Naveen, K. V., & Nagendra, H. R. (2004). An evaluation of the ability to voluntarily reduce the heart rate after a month of yoga practice. Integrative Physiological & Behavioral Science, 39(2): 119-125.
• Throll, D. A. (1982). Transcendental medication and progressive relaxation: their physiological effects. Journal of Clinical Psychology, 38(3): 522-530.
• Travis, F., & Miskov, S. (1994). P300 latency and amplitude during eyes-closed rest and Transcendental Meditation practice. Psychophysiology, 31: S67.
• Usharbudh, A. P. (1986). Yoga Sütras of Pataïjali with the exposition of Vyasa. The Himalayan International Institute, Pennsylvania.
• Uttl, B., & Pilkenton-Taylor C. (2001). Letter cancellation performance across the adult life span. The Clinical neuropsychologist, 15, 521-530.
• Udupa, K., Sathyaprabha, T. N., Thirthalli, J., Kishore, K. R, Raju, T. R., & Gangadhar, B. N. (2006). Alteration of cardiac autonomic functions in patients with major depression: a study using heart rate variability measures. Journal of affective disorders. 100: 137-141.
• Vempati, R. P., & Telles, S. (2002). Yoga based relaxation reduces sympathetic activity judged from base line levels. Psychological Reports, 90: 487-494.
• Vempati, R. P., & Telles S. (2002). Yoga based relaxation reduces sympathetic activity judged from base line levels. Psychological Reports, 90: 487-94.
• Vivekananda, Svämé. (2001). Conquering the Internal Nature: Raja Yoga. Advaita Ashram: Champawat, Himalaya.
• Vivekananda, Svämé. (1971). The Yogas and Other Works. Edited by Svämé Nikhilananda. Ramkrishana-Vivekananda Center, New York (pp.694).
• Vyas, R., & Dikshit, N. (2002). Effect of meditation on respiratory system, cardiovascular system and lipid profile. Indian journal of physiology and pharmacology, 46(4): 487-491.
• Vivekananda, Svämé. (2001). Conquering the Internal Nature: Raja Yoga. Advaita Ashram: Champawat, Himalaya.
• Vivekananda, Svämé. (1971). The Yogas and Other Works. Edited by Svämé Nikhilananda. Ramkrishana-Vivekananda Center, New York. (pp.694).
• Vdyananda Saraswati Svämé. (1985). The Brahmasutra. Deva Vedic Prakssana: Bandra, Bombay.
• Wallace, R. K., Benson, H., & Wilson, A. F. (1971). A wakeful hypometabolic physiologic state. The American journal of physiology, 221, 795-799.
• Wallace, R. K., Orme-Johnson, D. W., Mills, P. J., & Dillbeck, M. C. (1984).

Academic achievement and the paired Hoffman reflex in students practicing meditation. The International journal of neuroscience, 24(3-4): 261-266.
• Wallace, R. K. (1970). Physiological effects of Transcendental Meditation. Science, 167, 1751-1754.
• Walter, W. G., Cooper, R., Aldridge, V. J., Mccallum W. C., & Winter, A. L. (1964). Contingent negative variation: an electric sign of sensorimotor association and expectancy in the human brain. Nature, 203, 380-384.
• Woods, D. L, & Clayworth, C. C. (1985). Click spatial position influences middle latency auditory evoked potentials (MAEPs) in humans. Clinical EEG, 60: 122-129.
• Wewers, M. E., & Lowe, N. K. (1990). A critical review of visual analogue scales in the measurement of clinical phenomena. Research in nursing & health, 13(4): 227-236.
• Walton, K. G., Schneider, R. H., & Nidich, S. (2004). Review of controlled research on the transcendental meditation program and cardiovascular disease. Risk factors, morbidity, and mortality. Cardiology in review, 12(5): 262-266.
• Wallace, R. K., Benson, H., & Wilson, A. F. (1971). A wakeful hypo metabolic physiological state. American Journal of Physiology, 227: 795-799.
• Wewers, M. E., & Lowe, N. K. (1990). A critical review of visual analogue scales in the measurement of clinical phenomena. Research in Nursing and Health, 13: 227-36.
• Yadav, A., Tandon, O. P., & Vaney, N.(2002). Auditory evoked responses during different phases of menstrual cycle. Indian Journal of Physiology and Pharmacology, 46: 449-456.
• Yildirir, A., Kabakci, G., Akgul, E., Tokgozoglu, L., & Oto, A. (2002). Effects of menstrual cycle on cardiac autonomic innervation as assessed by heartrate variability. Annals of noninvasive electrocardiology, 7(1): 60-63.
• Yesavage, J. A., & Jacob, R. (1984). Effects of relaxation and mnemonics on memory, attention and anxiety in the elderly. Experimental Aging Research, 10(4): 211-14.
• ZAR, J. H. (2005). Biostatistical analysis. (4th ed.) Person Education (Singapore) Pvt. Ltd. Delhi, India.
• Zeier, H. (1984). Arousal reduction with biofeedback-supported respiratory meditation. Biofeedback and self-regulation, 9(4): 497-508.
• Zhang, W., Zheng, R., Zhang, B., Yu, W., & Shen, X. (1993). An observation on flash evoked cortical potentials and Qigong meditation. The American journal

of Chinese medicine, 21(3-4): 243-249