Short Communication

Effect of Sudarshan Kriya (meditation) on gamma, alpha, and theta rhythm during working memory task

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ABSTRACT

Aims: The present study focuses on analyzing the effects of Sudarshan Kriya yoga (SKY) on brain signals during a working memory (WM) task. To envision the significant effects of SKY on WM capacity (WMC), we chose a control group for contriving a cogent comparison that could be corroborated using statistical tests.

Subjects and Methods: A total of 25 subjects were taken in the study, of which 10 were allotted to a control group and 15 to an experimental group. Electroencephalograph was taken during a WM task, which was an automated operation span test before and after SKY with 90 days intervals. No SKY was given to the control group.

Statistical Analysis Used: *t*-test and one-way ANOVA were applied.

Results: SKY promoted the efficient use of energy and power spectral density (PSD) for different brain rhythms in the desired locations as depicted by the gamma (F8 channel), alpha, and theta 2 (F7 and FC5) bands. It was found that gamma PSD reduced for both phases of memory in the experimental group. Alpha energy increased during the retrieval phase in the experimental group after SKY. Theta 1 rhythm was not affected by SKY, but theta 2 had shown left hemispheric activation. Theta rhythm was associated with memory consolidation.

Conclusions: SKY had shown minimized energy losses while performing the task. SKY can improve WMC by changing the brain rhythms such that energy is utilized efficiently in performing the task.

Key words: Electroencephalograph; Sudarshan Kriya yoga; working memory.

INTRODUCTION

The word "Sudarshan" finds its origins in Sanskrit to mean: "Su" = right, "Darshan" = vision, and "Kriya" = purifying action. It is a rhythmic breathing activity consisting of the following five stages.[1-3] Ujjayi, Bhastrika, Om Chanting, Sudarshan Kriya yoga (SKY), and Yoga Nindra. It is a practice of wellness that reduces stress and produces relaxation. SKY can remove stress by making changes at the endocrine level and molecular level.[3]

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Stress and working memory capacity

Working memory (WM) is the memory of the presented stimuli that registers information for a brief span when triggered. WM Capacity (WMC) is defined as the successful maintenance of the stimuli during encoding with a simultaneous engagement in another mental operation. WM performances get affected by stress. It has an inverted-U-shaped relation in which moderate stress facilitates performance (manipulation component

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of WM) while higher levels impair performance.[4,5] Acute stress can have devastating effects on WM, which can be explained by the limited capacity theory. This theory states that the cognitive representation of stressful life events competes with the task demands for attention and that this trade-off leads to memory impairment.[6] Therefore, it is necessary to identify the brain activity that gets modified under the influence of SKY which in turn combats stress and enhances WMC. To gauge the influence of SKY on WMC, besides psychological scores, there should be physiological recordings that can cross-validate the findings. Electroencephalograph (EEG) is one such technique that can solve the problem of real-time brain activity measurement. In this study, only gamma (30–45 Hz), alpha (8–13 Hz), and theta (4–8 Hz) bands were considered due to their active roles in WMC. Gamma band oscillations are generally involved in the maintenance of WM information while alpha band activity reflects the active inhibition of the task-irrelevant information, and theta band oscillations underlie the organization of sequentially ordered WM items.[7]

Hypothesis

Based on aforementioned relations between stress and WMC, we hypothesized that SKY would enhance WMC. Since SKY reduces stress at the endocrinal and molecular level and is termed as an antidepressant technique, it would be equally instrumental in enhancing WMC.

SUBJECTS AND METHODS

Experimental design

A total of fifteen and ten subjects, of ages varying between 30 and 50 years, were selected for the experimental and control groups, respectively. The two groups were matched on age, education, and economic status. A 7 days workshop was held by the Art of Living (AOL) foundation, teaching SKY only to the experimental group. Prior to the SKY training, both groups underwent a 5 min base line recording (rest time) and a 20–25 min long WM test with simultaneous EEG recording. It was included as prerecording (duration of 30 min) of EEG data for rest and the WM task. After the 7 days workshop, each subject from the experimental group practiced SKY on their own under the monitoring of the experimenter daily, whereas the control group was left to continue with their existing lifestyles. After 90 days, a postrecording was done with a similar procedure as was adopted in prerecording showed in Figure 1.

Tools and techniques

Working memory task

Automated of operation span (AOSPAN):[8] It was an automated computer-based task in which the user was free from experimenter control. This comprised 15 trials and each trial consisted of remembering and retrieving letters along with solving mathematical problems. In the experimental conditions, letters remained onscreen for 800 ms. During the retrieval phase, the participants saw a 4:3 matrix of letters (F, H, J, K, L, N, P, Q, R, S, T, and Y). They were required to click the box next to the appropriate letters (no verbal response was required) in the correct order. The task took approximately 20–25 min to complete. The task was administered using E-prime software. Absolute scoring method was adopted to calculate AOSPAN score.

Electroencephalograph acquisition

Emotiv EPOC: EEG from each subject was recorded with an EEG device Emotiv EPOC; a 14-channel (followed the international 10–20 locations), neural signal acquisition, and processing wireless neuron headset. The sampling frequency was 128 Hz with the reference electrode placed at the mastoid location. Data were acquired in a quiet and ventilated room.

Electroencephalograph signal analysis

As there were fifteen trials for each encoding and retrieval phase, the raw EEG data was segmented for each trial and each EEG channel. Then a Butterworth bandpass filter having a cut-off frequency (2-45 Hz) was applied on each segment of the data. For removing the noise, a wavelet-based denoising technique was used. For extracting the spectral bands gamma (30-45 Hz), alpha (8–12 Hz), and theta (4–8 Hz), discrete wavelet packet was applied. For calculating the relative wavelet energy of theta 1 (4–6 Hz) and theta 2 (6–8 Hz) bands, the signal was decomposed using wavelet packet transform up to the 6th level.[9] Power spectral density (PSD) was calculated using Welch method.

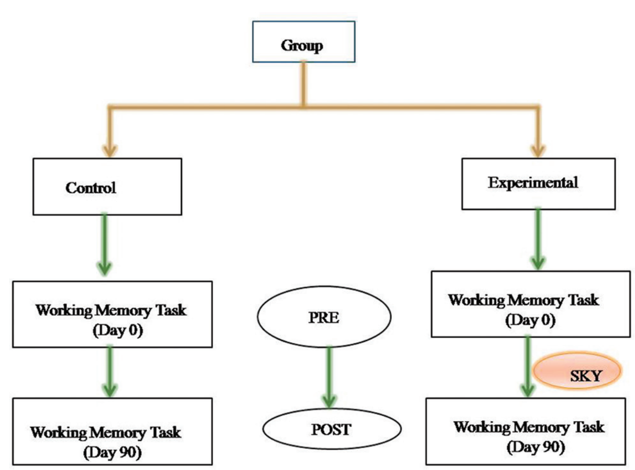

Figure 1: Overall procedure of experimental design adopted in this research study

Statistical analysis

Student's *t*-test was applied to find out the significant differences in AOSPAN scores and all the EEG features (except theta band) for encoding and retrieval trials at the probability 0.05. Univariate general linear model (GLM) for two-way ANOVA using one dependent variable was applied for theta 1 and theta 2.

RESULTS

There was an increase in AOSPAN scores for the postexperimental group (90 days) in comparison to the control group [Figure 2]. In this study, only frontal, frontocentral, occipital, and parietal channels were considered because these locations involved in the task of WMC.[10,11] There was a significant reduction in gamma PSD during the encoding phase of WM for channel F7 (t = 2.10, P = 0.040), FC5 (t = 2.88, P = 0.005), FC6 (t = 2.54, P = 0.014), O1 (t = 2.12, P 0.038), O2, P7 (t = 7.8, P = 0.00), and P8 (t = 3.28, P = 0.002) except F8 (t = −6.091, P = 0.00). Furthermore, there was a significant reduction in gamma PSD for the retrieval phase of WM for channel F7 (t = 2.66, P = 0.010), FC5 (t = 2.10, P = 0.040), FC6 (t = 314, P = 0.003), O1 (t = 2.46, P = 0.017), O2 (t = 2.18, P = 0.033), P7 (t = 6.30, P = 0.00), and P8 (t = 2.80, P = 0.006) except F8 (t = −3.28, P = 0.002) as shown in Figure 3. Alpha energy increased (t = −3.902, P = 0.018) after SKY as showed in Figures 4 and 5. In the control group (pre and post), alpha energy of encoding phase was higher than retrieval phase. A similar trend followed in the preexperimental group, while the effect of SKY was observed in the postexperimental group where the retrieval phase had more energy. Univariate GLM using two-way ANOVA was applied for group*theta type (theta 1 and 2) and group*memory phase (Encoding and retrieval). For group*theta type, a significant difference came for channel F7 (F = 28.40, P = 0.00), F8 (F = 42.96, P = 0.00), FC5 (F = 27.06, P = 0.005), and FC6 (F = 45, P = 0.00). For group*memory phase, a significant difference came in the channels F7 (F = 6.71, P = 0.01), F8 (F = 14.67, P = 0.00), FC5 (F = 7.8, P = 0.005), and FC6 (F = 5.73, P = 0.017). The left hemispheric dominance was found in theta 2 PSD band as shown in Figure 6.

DISCUSSION

The focal objective of this pilot study was to establish a relationship between the practice of SKY and WM capacity through information rendered by EEG spectral bands such as theta, alpha, and gamma. Previous literature indicated for a role of SKY in stress reduction.[3] We hypothesized that since stress had a negative correlation with WMC, therefore, reducing stress would ultimately enhance WMC. These effects were measured using AOSPAN and an EEG signal analysis. The score saw an increase in both the groups, but the difference was more in the experimental group. To discern the effects of SKY on brain rhythms, EEG spectral analysis was performed for gamma, alpha, theta 1, and theta2. SKY promoted the efficient use of energy and PSD for different brain rhythms in the desired locations as depicted by the gamma (F8 channel), alpha, and theta 2 (F7 and FC5) bands. According to the neural efficiency hypothesis, neural activity in the postexperimental group started working more efficiently.[12] As a consequence, the subjects of this group faced no difficulty in removing content from maintenance when no longer needed. They quickly adapted with the task load as AOSPAN was an indicator of cognitive control efficacy. One

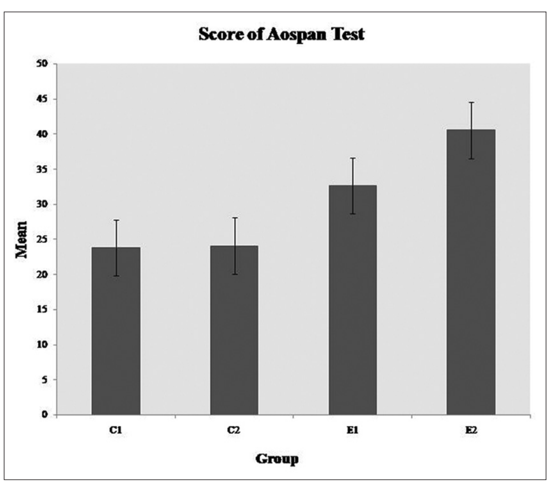

Figure 2: Scores of working memory capacity (automated of operation span task) for both groups. Here, C1 = precontrol group prior Sudarshan Kriya yoga at day 0, C2 = postcontrol group at day 90, E1 = prexperimental group before Sudarshan Kriya yoga, and E2 = postexperimental group after Sudarshan Kriya yoga at day 90

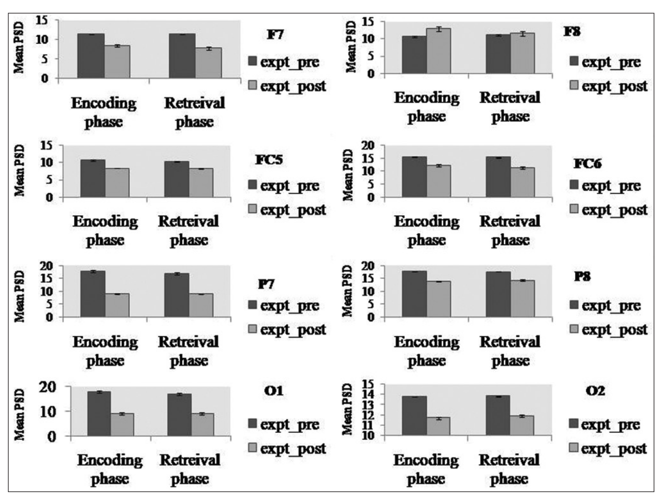

Figure 3: Changes in the gamma power spectral density under the effect of Sudarshan Kriya yoga for the experimental group. Here, experimental prerepresented experimental group at day 0 and experimental postrepresented experimental group at day 90 for channels F7, F8, FC5, FC6, P7, P8, O1, and O2. Here, the unit of power spectral density was dB/Hz

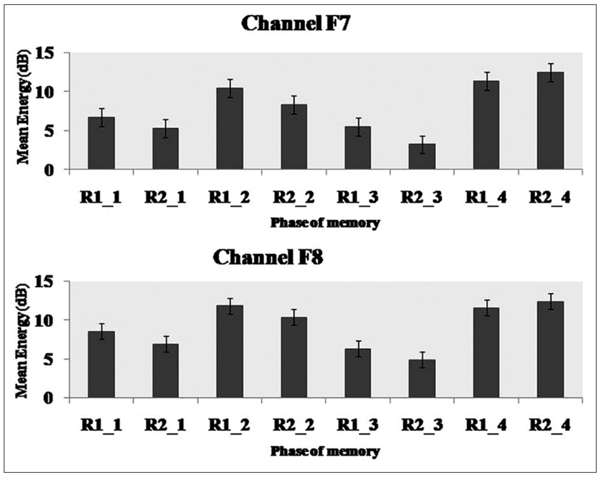

Figure 4: Frontal distribution of alpha energy for both groups and phases of memory. Here, R1 = precontrol group prior Sudarshan Kriya yoga at day 0, R2 = postcontrol group at day 90, R3 = preexperimental group before Sudarshan Kriya yoga, and R4 = postexperimental group after Sudarshan Kriya yoga at day 90. Here, 1 represented encoding phase and 2 represented retrieval phase

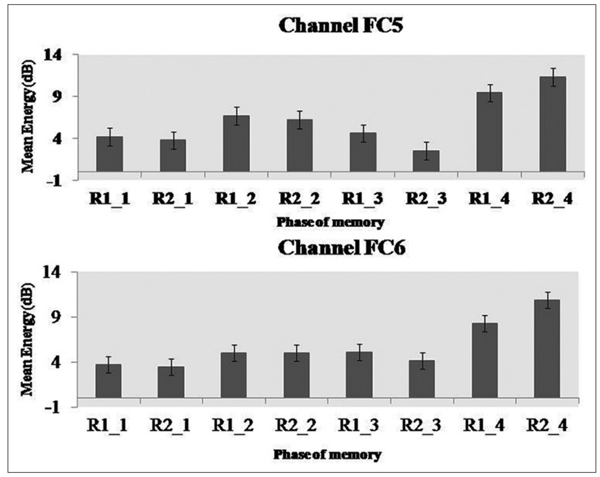

Figure 5: Frontocentral distribution of alpha energy for both groups and phases of memory. Here, R1 = precontrol group prior Sudarshan Kriya yoga at day 0, R2 = postcontrol group at day 90, R3 = preexperimental group before Sudarshan Kriya yoga, and R4 = postexperimental group after Sudarshan Kriya yoga at day 90. Here, 1 represented encoding phase and 2 represented retrieval phase

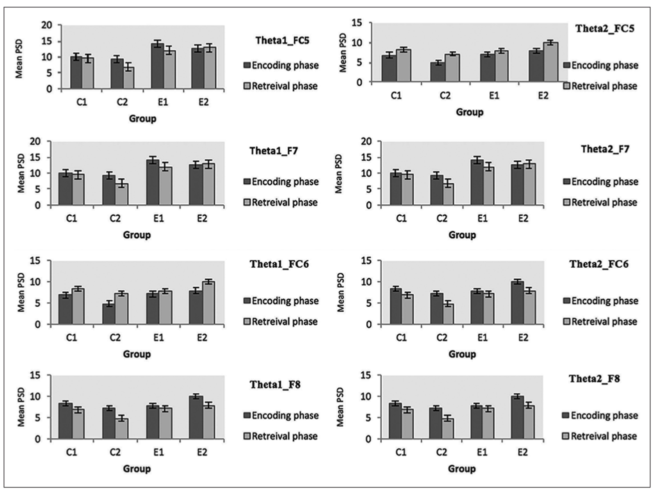

Figure 6: Theta power spectral density distribution for theta type (theta 1 [4–6 Hz] and theta 2 [6–8 Hz]) in both groups. Here, C1 = precontrol group prior Sudarshan Kriya yoga at day 0, C2 = postcontrol group at day 90, E1 = preexperimental group before Sudarshan Kriya yoga, and E2 = postexperimental group after Sudarshan Kriya yoga at day 90. Power spectral density measured in unit dB/Hz

more theory seemed to fit the results, the global space theory. According to this, resource allocation was built in a productive manner, such that networks between nodes were formed for task-relevant stimuli rather than irrelevant stimuli. To paraphrase, global workspace neurons were mobilized (energy loss) in effortful tasks and were efficiently maintained by SKY. As described by Dehaene *et al*.,[13] an effortful task required a higher global workspace activation that could decline after habituation for that task. It seems plausible that WMC increased after SKY, because SKY reduced the latency of activation. Furthermore, the left hemispheric activation in theta 2 again reflected the effect of SKY in WMC as it had role in processing alphabets.[14] This result concluded that the role of SKY during the task along and the EEG features demonstrated SKY to be an effective method of training on comparing both the groups. In our knowledge, this is the first study done so far that attempts at establishing the role of SKY in improving WMC.

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Conflicts of interest

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