



SRI SRI INSTITUTE FOR ADVANCED RESEARCH

Art of Living Research Wing

A White Paper Series on Sudarshan Kriya

A White Paper on Sudarshan Kriya and Brain Function

Introduction

Our Brain

The brain is the most complex organ of the human body. A human brain is what differentiates us from other species on the planet. Weighing around three pounds, it is the base for vital functions such as intelligence, sense perception, social behavior, emotions, thought formation and body movement. The brain consists of three main parts: cerebrum, cerebellum and brainstem. While the cerebrum perceives the senses, maintains emotions and learning, the cerebellum regulates posture and maintains balance in the body. The brainstem is the center for all autonomic functions like breathing, heart rate variability, digestion, sneezing, etc.

The brain is divided into two hemispheres, left and right, which control opposite sides of the body. The left hemisphere supervises the cognitive functions, speech and comprehension, while the right hemisphere supervises creativity, spatial ability and musical skills. They work in synchronization with each other. Brain is the communication and processing center exchanging information internally, and with other parts of the body through a series of network forming brain cells called neurons. The human brain has approximately 100 billion neurons and these neurons consists of cell bodies which form the gray matter, and myelinated axons extending from cell bodies, connecting the brain areas and exchanging information, which form the white matter. Gray matter also includes the glial cells supporting the neurons. Gray matter is responsible for functional processes, balancing motor control and cognition, while white matter allows faster transportation of signals. One of the ways to measure brain activity and its functions is by measuring the electrical signals fired by the neurons. This enables us to study the activity of the brain under various conditions.

Brain Waves

Neurons communicate with each other using electrical signals. Synchronized electrical communication between the neurons produce a wave of signals known as brain waves. These brain waves are captured via the computer-generated Electroencephalogram (EEG).

There are five types of brain waves, categorized by their frequency into bands of slow, medium and fast waves. From the slowest to fastest, the spectrum of brain waves includes the delta, theta, alpha, beta and gamma waves. These signals are measured in Hertz (cycles per second).

Delta waves (0.5-3 Hz):

Delta waves are low frequency and loud (like drum beating) waves. They are usually produced during deep sleep and meditation. Healing and restorative activities happen when the brain is in this frequency. Therefore, it is essential to experience deep sleep or meditate, especially when the body requires extensive and faster healing.

Theta waves (3-8 Hz):

Theta waves are produced during REM sleep, a twilight phase between wakefulness and deep sleep. They are also produced by the brain while dreaming, having intuitive thoughts and during vivid imagination. Theta waves also occur while performing repetitive tasks that require little attention or focus. Theta waves indicate inner focus, and blissful states.

Alpha waves (8-12 Hz):

Alpha waves lie in the middle of spectrum of brain waves. They are predominant during the resting and relaxed phases of the brain. Alpha waves are produced in some meditative states where the mind is not very focused on a single thing. Alpha waves are associated with an increased perception of calmness.

Beta waves (12-38 Hz):

Beta waves represent the waking state of consciousness when the brain is involved in multiple processing and cognitive tasks. These waves are formed during decision-making and focused mental activity. Beta waves are predominantly high while solving a mathematical calculation or when involved in an intellectual activity.

Gamma waves (38-42 Hz):

Gamma waves have the highest frequency in the spectrum of brain waves. They are predominant during simultaneous information processing, intense focusing and problem solving. However, they are also noticed when one is in state of love, altruism or expanded states of consciousness and higher virtues.

Yet another wave function captured by EEG is known as P300 (P3). This wave is elicited when a thought is generated during a process or decision-making in response to a particular event. Therefore, the measure of this signal in terms of amplitude, timing and topography is a measure of cognitive function in brain. Differentiated further into P3a and P3b, they measure the attention and cognitive process respectively.

Brain waves under stress

Stress is a precursor for many pathological physiological conditions in the body. Stress releases a chemical in the blood known as cortisol, which reduces brain's ability to function properly. High levels of cortisol produced by body under stress can damage the synaptic activity and disrupt communication between brain cells. It can also damage the hippocampus and hippocampus-dependent learning and memory. Chronic stress also impairs the functions of hypothalamic-pituitary-adrenal axis (HPA), the amygdala, and the frontal lobe of the brain.

The traditional methods of stress detection have the major drawback of invasiveness. An EEG is a non-invasive, accurate and reliable method of stress detection. Along with detecting various brain functions, EEG also measures the functional interactions between the network of neurons spread in different parts of the brain. Inter-hemispheric coherence determines functional integration, network formation, symmetry and connectivity between the right and left cerebral hemispheres. A higher coherence indicates a faster flow of information between the hemispheres. It also regulates the balance and synchrony between logic and creativity in a person.

Sudarshan Kriya Yoga(SKY)

Sudarshan Kriya Yoga is a technique taught by the Art of Living Foundation in more than 180 countries with more than 6 million practitioners across the globe. It is taught in various modules across various age groups in different parts of the world.

SKY is a cyclic rhythmic breathing technique with its roots in traditional yoga. The 25 minutes process includes three yogic components – pranayama, Om chanting and Sudarshan Kriya. The pranayama is done using the Ujjayi breath. Ujjayi involves experiencing the conscious sensation of the breath touching the throat. This slow breathing technique is performed at a rate of 2–4 breaths per minute (bpm). This technique improves lung capacity, allowing more air to pass through the lungs. ‘Om’ is chanted three times with prolonged exhalation. Lastly, Sudarshan Kriya rhythmic breathing is done in two variations: long SKY, which is done under Gurudev Sri Sri Ravishankar’s recorded instruction, and short SKY, which can be done at home taking slow (20 bpm), medium (40–50 bpm), and fast (60–80 bpm) breaths. The entire technique is done in a seated posture with eyes closed.

Research studies on Sudarshan Kriya Yoga and Brain function

Several studies have measured the changes in EEG and P300 amplitude in the brain with SKY. Below are their summaries.

1. A quantitative analysis of EEG among Art of Living teachers after Sudarshan Kriya Yoga

Bhatia et al. studied^[1] used EEG to study the impact of SKY on brain function, with the objective to understand the long-term effect of regular SKY practice. The study evaluated EEG readings obtained from practitioners during the SKY practice to understand the long-term effect of regular practice. The study included 5 healthy women Art of Living teachers who had been practicing SKY for more than 2 decades. EEG was measured at multiple time points during the long SKY session. An increase in coherence was observed towards the end of the SKY session predominantly in the fronto-central regions in the beta band. The increased coherence suggests increased connectivity between different parts of the brain, which in turn is suggestive of more efficient information processing. There was an increased alpha activity in the posterior regions during the SKY practice. In addition, a central midline theta activity was observed. The resting EEG demonstrated an increased focal beta activity. The central midline theta activity suggests activation, and the increased alpha is suggestive of relaxation. Thus, there is a combined state of relaxed awareness in the brain during SKY.

Summary: EEG measurements during SKY shows that the brain is both relaxed and active during SKY, and after SKY. There is greater coherence, which indicates efficient information processing.

2. Using EEG to evaluate changes in brain function before and after Sudarshan Kriya Yoga

Multiple studies have used EEG to explore the relationship between mental states and brain signals. A study by Chandana et al.^[2] collected resting EEG data for 43 subjects before and after the practice of SKY. Out of the 43 participants, 10 participants had been practicing SKY regularly for over 8 years, and were grouped as 'long term practitioners'. The other 33 had been practicing SKY for a shorter time, and were labeled as 'short term practitioners'. EEG readings at the baseline (pre -SKY), showed that most subjects were not in a relaxed state before SKY. After SKY, increased electrical energy was seen in the brain of the practitioners, and the changes in the EEG reflected that participants were in a state of both relaxation and alertness. 84% of the participants demonstrated an increase in electrical energy of alpha brain waves, indicating an alert and relaxed state of mind. 97% of them demonstrated an increase in beta wave energy, indicating an alert and awake state of consciousness. 88.4% of them showed increased energy in delta waves, which is akin to experiencing a deep sleep state. Finally, all the study participants showed an improvement in theta waves, indicating that the subjects were in an extremely relaxed state. While all practitioners showed an increase in energy of brain waves, long term practitioners showed a 2-3 fold increase compared to short term practitioners. Overall, after SKY, the subjects were in an extremely relaxed state while still being alert to the external surroundings.

Summary: A study comparing EEG changes in the brain before and after SKY indicated that during SKY, practitioners experienced a state of deep relaxation while still being alert to the environment. 84% of the participants demonstrated an alert and relaxed state of mind. 97% of them demonstrated an alert and awake state of consciousness and 88.4% of them showed an increase in delta waves, which is akin to experiencing a deep sleep state. All of them showed an increase in theta waves, which denotes that their brain was experiencing a relaxed state. They also experienced an increase in energy and alertness.

3. Activation and synchronization of Global brain rhythms post Sudarshan Kriya Yoga

It has been shown that respiratory rhythms change the electrical activity in the brain and create neural-oscillations. A study by Bhaskar et al.^[3] evaluated the changes in brain rhythms following the practice of Long SKY. The study assessed 40 individuals who had learnt and practiced SKY for at least 1 year

prior to the study. EEG was recorded before and after the long SKY practice to measure brain rhythms. Spectral frequency was calculated for all 5 frequency waves (Alpha, Beta, Theta, Delta and Gamma) at the frontal, central, parietal, temporal and occipital regions. It was found that post SKY, there was an increase in overall brain activation. Neuronal oscillations increased significantly in all frequency bands bilaterally. The change in spectral power of gamma and beta bands (increased by 10%-15%) was greater than in delta, theta and alpha (increased by 4%-8%) bands. Inter-hemispheric synchronization (between right and left hemisphere) increased after SKY, which indicates increased connectivity, complexities, and symmetry between the right and left cerebral hemispheres. The findings suggest that SKY generates a global brain rhythm predominantly in the high-frequency range and increases synchrony between the left and right cerebral hemispheres.

Different frequency components were extracted and analyzed further to create an association between brain states and SKY. Alpha power increased significantly across all regions after SKY. Greater alpha activity correlates with lower anxiety, reduced stress, increased calmness and greater positivity. An increase in the beta power suggests alertness and cortical activation. Delta power also increased significantly and bilaterally after long SKY. It is usually connected with motivational processes, higher emotional involvement and cognitive processes related to attention. Increased theta power is commonly observed in advanced practitioners but with long SKY, even the newer practitioners with less experience, had a significant increase in theta power across all regions of the brain. Stronger theta power is usually associated with bliss, deep peace and low thought mental states. High frequency gamma waves are usually found in long term practitioners of meditation or pranayama. They are associated with cognitive functions, visual perception, attention, memory, and long-range neuronal communications. Like theta power, gamma activity was increased across the brain, both in long term and short term SKY practitioners.

Summary: An EEG evaluation of practitioners before and after a session of Long SKY revealed that a single session of long SKY generates a profound global rhythm in the brain. An increase in power for all spectral bands (Alpha, Beta, Theta, Delta and Gamma) was seen. Even the newer SKY practitioners demonstrated a shift in gamma and theta bands, which is usually only seen in advanced meditation practitioners. Inter-hemispheric synchronization also increased between the right and left hemispheres, indicating greater autonomic control and generating a state of awareness with deep rest. Overall, the study indicated that SKY improves attention, memory, emotional and autonomic control along with enhancing cognitive functions, all of which eventually augments physical and mental well-being.

4. P300 Amplitude normalization following Sudarshan Kriya Yoga in Dysthymia patients

Murthy et al.^[4] studied the impact of SKY practice on dysthymia (persistent depression). This study compared the P300 amplitude and depression scores in 24 patients diagnosed with depression : 15 with dysthymia and 9 with melancholic depression. The control group consisted of 15 healthy individuals normal on P300 and depression scale. P300 is a wave potential produced during an event. Depressed people have a particular EEG brainwave abnormality which is measured by P300 ERP amplitude which is usually lower compared to healthy adults. At baseline assessment prior to the intervention, subjects suffering from depression demonstrated abnormal and lower EEG brainwave, measured by the P300 ERP amplitude, as compared to healthy adults. Patients suffering from depression were provided SKY as an intervention and were encouraged to practice daily for 90 days. Post 90 days of SKY, a significant improvement was noted in the depression scores as measured by the P300 amplitude and standardized scales. By Day 90 P300 ERP amplitude in patients with depression who practiced SKY were similar to that of healthy individuals, indicating the effectiveness of SKY practice in treating depression.

Summary: Murthy et al. studied the efficacy of SKY amongst dysthymic patients. The study compared the depression scores and P300 ERP amplitude readings of patients with depression with healthy controls. At baseline, the readings of patients with depression were found to be lower in amplitude and abnormal, compared to healthy controls. The patients suffering from depression were provided SKY and the readings were recorded again after 90 days of SKY practice. At the 90 day assessment, the EEG pattern in patients with depression who practiced SKY was similar to that of healthy individuals, indicating the effectiveness of SKY practice in treating depression.

5. Electrophysiologic evaluation of Sudarshan Kriya Yoga: an EEG, BAER, P300 study perspective

EEG changes were recorded by Bhatia et al.^[5] in 19 SKY practitioners in a resting state, not during the practice of SKY, and compared with the EEG patterns of 16 controls (doctors and research scientists who did not practice SKY, yoga or meditation). No significant differences were found on the BAER or P300 latency measures. A significant increase in beta activity was observed in the left frontal, parieto-occipital and midline regions of the brain in the SKY practitioners, as compared to the controls. These results were interpreted by neurologists as indicative of increased mental focus/heightened

awareness. It is striking to note that SKY practitioners displayed significantly greater mental alertness (beta activity) than the control group of physicians and medical researchers, whose profession requires development and daily use of these very skills.

Summary: Brain activity of 19 SKY practitioners was recorded and compared with 16 medical professionals using EEG, P300 and BAER. The results showed increased beta wave activity in SKY practitioners, compared to the controls which is indicative of increased mental alertness in the SKY practitioners even during resting stage.

6. Effect of Sudarshan Kriya Yoga on working memory

Creating and storing memories involves complex neural processes. The long-term memory functions like an archive, while the working memory, allows us to store small amounts of information in the brain, for a brief period, so that we can perform tasks and function. A simple analogy for working memory is the computer RAM. A simple example of a working memory is remembering all the items to buy when you are at the grocery store, or remembering where you kept your keys. Working memory is important for everyday reasoning and decision-making. Stress has an adverse effect on working memory. Although short bursts of a reasonable amount of stress can increase working memory, acute and chronic stress has a debilitating effect on it. A study by Chandra et al.^[6] analyzed the effect of SKY on brain signals of 25 subjects using EEG, during a working memory task: 15 subjects were enrolled in the SKY group and 10 in the control group. The SKY group learnt and subsequently practiced SKY for 90 days. Control group did not receive any intervention. EEG recordings were taken during the working memory task at baseline (pre-SKY) and at 90 days after SKY practice. An automated computer-based test was used to test the working memory. The test contained 15 trials, and each trial consisted of remembering and retrieving letters along with solving mathematical problems. Working memory scores increased in the SKY group after 90 days of practice. The EEG recording for the SKY group showed that they experienced diminished energy losses while performing the working memory task. SKY can improve working memory capacity through changing the brain rhythms so that energy is utilized with higher efficiency while performing the task at hand. SKY promotes the efficient use of energy of gamma, alpha and theta bands at the desired locations.

Summary: SKY improves Working Memory Capacity as shown by the improvement in the working memory test scores after 90 days of SKY practice. The EEG of SKY practitioners at 90 days of practice, showed changes in brain waves that corresponded to a more efficient utilization of energy while performing tasks at hand. Working memory allows us to store small amounts of information in

the brain, for a brief period, so that we can perform tasks and function in day to day life. Improvements in working memory capacity, as measured by working memory tests, have a role in reducing stress, improving cognition and decision-making abilities.

7. Impact of Sudarshan Kriya Yoga on Improving Mental Workload Capacity

Mental workload refers to the quantum of mental resources required to perform a set of concurrent tasks. Sustained high mental workload can cause mental fatigue, diminish performance, and create detrimental health effects in the long run. Workload capacity refers to the brain's ability to process information. A reduced workload capacity leads to a slower information processing by the brain. Level of mental workload can be interpreted through the HRV (heart rate variability) component of the ECG. A study by Chandra et al.^[3] assessed the ECG of 25 participants for workload tolerance and stress, pre and post SKY, and compared them with a control group. Of the 25 subjects, 15 were enrolled in the experimental group which learnt, and subsequently practiced SKY for 90 days. The control group consisted of 10 participants who were not provided an intervention. Assessments were conducted at baseline (day 0) and at day 90 after intervention. During the assessment, the participants performed 2 different types of tasks - one set of tasks that required low workload capacity (LWL) and another set of tasks that required high workload capacity (HWL) by means of MATB-II. Workload was also assessed by a subjective Workload Rating scale (WRS). Multi-Attribute Task Battery (MATB-II) is a computer-based task designed to evaluate operator's performance and workload consisting of two-dimensional tracking, system monitoring, communication and resource management tasks. The assessment was done on MATB for 5 minutes at baseline and then 8 minutes for LWL and HWL each on Day 0 (pre). Their EEG and ECG was obtained during the tasks and their performance on the task was analyzed at the above mentioned point for both experimental and control group. After 30 and 90 days of SKY practice, post data for both the groups was obtained similarly. Their EEG and ECG was obtained during the tasks and their performance on the task was analyzed.

The SKY group performed significantly better on day 90 for both LWL and HWL tasks. Comparison was done for theta, gamma and alpha waves between the two groups. Under rest conditions the alpha and beta energy decreased in the control group while it increased in the SKY group. SKY group made fewer errors and their response time was reduced. The control group had a slightly improved performance for LWL tasks, but their performance for HWL tasks worsened on day 90. SKY had a positive effect on cognitive flexibility which was reflected in the practitioner's reduced response time. This improved attentional switching and increased the capacity for workload tolerance. SKY practitioners also experienced increased alpha brain activity in rest conditions, which is positively correlated with feeling calm and inversely correlated with stimulus discriminability and attentional

suppression of distracting information. In other words, the ability to focus was enhanced, and SKY practitioners were able to not get distracted by other stimuli, and stay focused while performing the tasks.

Summary: The practice of SKY increases mental workload capacity. Workload capacity is defined as the ability of the brain to process information. After the practice of SKY, participants made fewer errors and took less time to complete tasks that required a high level of mental workload. They also exhibited increased alpha waves which promotes the ability to focus and not get distracted easily.

8. Effect of SKY on stress tolerance

A study by Chandra et al.^[8] studied the effects of SKY on stress tolerance using a stress determination test (DT). Stress determination test is a computer based test used to assess the reactive stress tolerance. DT is a mental stress simulator as well as a physiological test. The DT-test requires the subject to discriminate colors and acoustic signals, to memorize the relevant characteristics of stimulus configurations, response buttons as well as the assignment rules, and to select the relevant reactions according to the assignment rules laid down in the instructions and / or learned during the course of the test. The difficulty of the DT-Test lies in the production of continuous, sustained, brisk and varied reactions to rapidly changing stimuli. Depending on the stimulus/reaction mode, four types of scores can be obtained from a DT namely, average response/reaction time, number of total responses, number of delayed responses, and number of omitted reactions. Chandra et al.^[8] enrolled 10 participants in the control group and 10 in the experimental (SKY) group. The SKY group learnt the SKY practice and subsequently practiced it for 30 days. EEG was measured before and after the DT session at baseline, and again at before and after DT test after 30 days of SKY practice. The participants in the SKY group demonstrated an improved performance on the DT at 30 days assessment. A significant improvement in the number of total responses was seen in the SKY group post 30 days SKY practice. Also the average reaction time and number of delayed responses decreased in the SKY group. Another observation in the SKY group showed a significant improvement in the alpha band in the SKY group post The SKY group made less errors, responded to more questions and took less time, i.e., it was easier for them to handle the task. However, the control group showed no major difference between pre and 30 days post scores. It indicates that under the same stressor task, the brain can bear more stress after the exposure of SKY, i.e., stress tolerance increases. After SKY, significant changes were found in all the participants, but subjects who were more stressed as determined from the DT test, benefitted more compared to the less stressed subjects.

Summary: A study measured the impact of SKY on mental stress tolerance using a stress determination test (DT), which is a computer based test used to assess the reactive stress tolerance. After 30 days of SKY practice, the average response time and delayed reactions decreased for SKY practitioners, while the total number of responses during the task increased. Subjects found it easier to handle the task, indicating that stress tolerance increases after SKY. SKY is a highly effective stress reducer. It improves our ability to tolerate stress and enhances cognitive performance under stress and otherwise.

Summary of Research findings

SKY has multiple mental and physical benefits. Studies evaluating the impact of SKY on brain function corroborate these findings, and shed light on the way SKY transforms our entire physiology by changing how our brain functions.

- A study demonstrated that SKY practice creates a state of concurrent deep relaxation and awareness, as indicated by significant increases in alpha brain wave activity for relaxation, and beta brain wave activity for awareness. An increased state of coherence between neurons indicates efficient information processing.
- A study comparing EEG indicates that during SKY, people experience a state of deep relaxation while still being alert to the environment. 84% of the participants demonstrated an alert and relaxed state of mind. 97% of them demonstrated an alert and awake state of consciousness and 88.4% of them showed increase in delta waves, which is akin to experiencing a deep sleep state. All of them experience an increase in theta waves which denotes that they are in an extremely relaxed state. They also experience an increase in energy and alertness.
- A single session of long SKY creates a profound global rhythm in the brain. An increase in power of all spectral bands (Alpha , Beta, Theta, Delta and Gamma) was seen in the study conducted on SKY practitioners. Even the newer practitioners show a shift in gamma and theta bands indicative of faster information processing and state of bliss and inner focus respectively. This is usually only associated with advanced practitioners of SKY. Inter-hemispheric synchronization also increased between the right and left hemispheres, providing greater autonomic control and state of awareness with deep rest. Overall, the study indicates that SKY leads to better attention, memory, emotional and autonomic control along with enhanced

cognitive functions, which eventually improves physical and mental well-being.

- The efficacy of SKY amongst dysthymic patients was studied. The study compared the depression scales and ERP amplitude readings of patients with depression with healthy controls. At baseline, the p300 amplitude readings of patients with depression were found to be lower in amplitude and abnormal, compared to healthy controls. The patients suffering from depression were provided SKY and the readings were recorded again after 90 days of SKY practice. At 90 day assessment, the p300 amplitude pattern in patients with depression who practiced SKY was similar to that of healthy individuals.
- Brain activity of 19 SKY practitioners was recorded and compared with 16 medical professionals using EEG, P300 and BAER. The results show increased beta wave activity in SKY practitioners compared to the controls which is indicative of increased mental alertness in the SKY practitioners even during resting stage.
- SKY improves Working Memory Capacity by changing the brain waves such that energy is utilized efficiently in performing the task at hand. Working memory comprises processes in our brain that allow us to store small amounts of information for a brief period so that our body can carry out operations. Changes in working memory capacity, as measured by different brain rhythms, have a role in reducing stress, improving cognition and decision-making abilities.
- The practice of SKY increases mental workload capacity. Workload capacity is a term that reflects the ability of the brain to perform information processing. After practice of SKY, participants made fewer errors and took less time to complete tasks that required a high level of workload in the brain. They also exhibited increased alpha waves which promote the ability to focus and not get distracted easily.
- In a study that measured stress tolerance using a stress determination test (DT), a computer based test used to assess the reactive stress tolerance, it was found that after the SKY practice, the average response time and delayed reactions decreased, while the total number of responses during the task increased. Subjects found it easier to handle the task, indicating that stress tolerance increases after SKY. SKY is a very effective stress reducer. It improves our ability to tolerate stress and enhances cognitive performance.

Conclusion

Brain function and states of consciousness are captured via the EEG through different brain signals. EEG analysis shows relaxed and alert state of mind among SKY practitioners. Even novice SKY practitioners show profound changes in brain rhythms, including more power in theta and gamma waves, which indicate blissful states as well as higher cognition. Studies also demonstrate improvement in cognitive functions, working memory capacity and emotional control after SKY practice due to a reduction in stress. Increased workload tolerance among daily SKY practitioners is also noted.

About Sri Sri Institute for Advanced Research

Sri Sri Institute for Advanced Research (SSIAR) is the research wing of The Art of Living. SSIAR's mission is to apply and share the science of Global Ancient Knowledge Systems to the challenges of today. Its vision is to become an internationally renowned center of excellence for scientific enquiry into Global Ancient Knowledge Systems.

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