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Investigate the Effect of Yoga and Meditation Using a Brain-Computer Interface Device

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Abstract: Yoga and Meditation practices started in ancient traditions and have become a popular lifestyle practices due to the linked benefits in improving mental and emotional well-being. Yoga is a physical activity and Meditation is a non-physical activity that involves maintaining a sustained state of physical fitness and mental relaxation. The scientific community is working hard to examine and quantify the impact of these practises, particularly on the brain. EEG data processing allows for a better understanding of the brain's intricate inner operations. Yoga and meditation EEG may allow access to mental states other than normal awareness. The goal of this study is to get fresh insights into the nature of EEG signals of both yoga and meditations. The captured signals are pre-processed and classified into five sub bands delta, theta, alpha, beta and gamma. For each sub band, statistical features such as mean and standard deviation were extracted. Furthermore, band power for all sub bands also removed. Finally approximate entropy and sample entropy features were extracted. All these features of yoga and meditation categories were analysed and compared.

Keywords: Electroencephalogram (EEG), Yoga, Meditation, Band power, Statistical features, Entropy features.

1. Introduction

1.1. Yoga

Yoga derives from extensive and age-old physical positions, breathing techniques, meditation techniques, mantras, and ethical teachings are all included in this spiritual system. The ultimate goal of these techniques is to access pure consciousness and achieve "waking up." More and more studies are recognizing yoga's benefits for treating stress-related illnesses and psychiatric disorders, as well as for enhancing both mental and physical wellness. However, the applicability of these findings has been constrained by the significant variety of yoga practices and the poor methodological quality. In addition to this, prior research on yoga has revealed two significant flaws.

First, yoga consists of a variety of elements that have only partially been researched and distinguished in the past [1]. We don't fully understand how every element of yoga functions on its own or the effects of different mixtures of these elements. Second, in the past, yoga's ethical component has frequently been ignored. Yoga bibliometric analysis research found that only 10% specifically included lectures on the theory of yoga or ethics. However, traditional yoga practitioners have argued that all of yoga, including its ethical components, should be practiced.

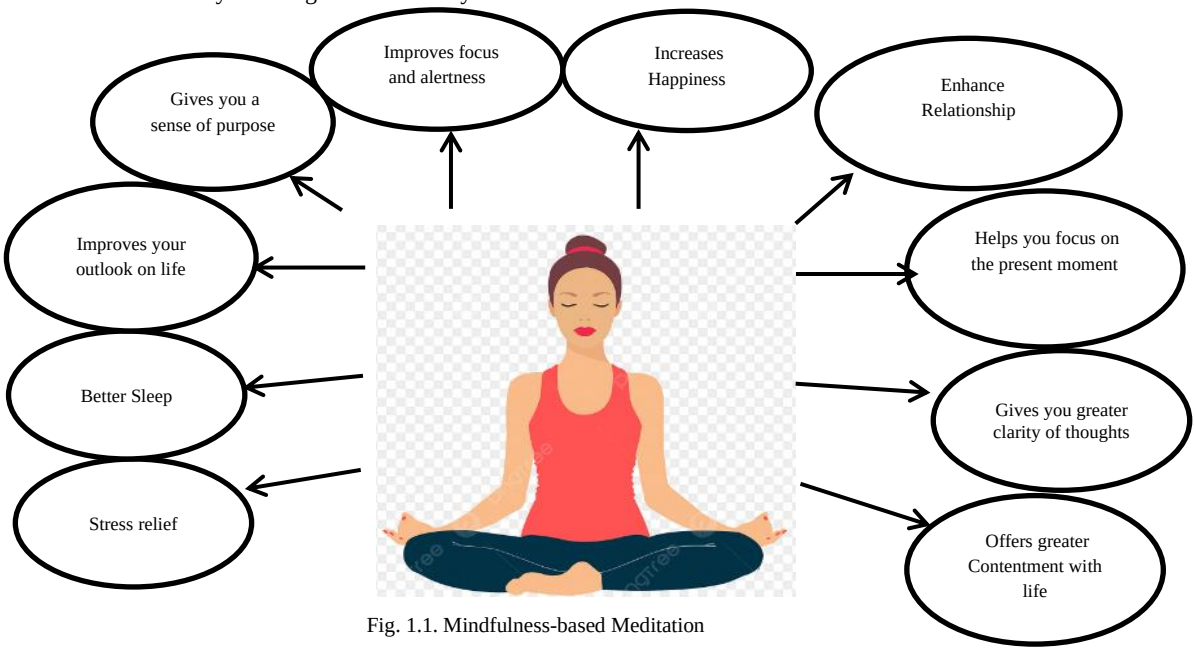

Fig. 1.1. Mindfulness-based Meditation

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1.2. Meditation

The goal of mindfulness-based stress reduction in figure 1.1, a structured programmer that involves gentle Hatha yoga, group discussions, and methodical attention to each area of the body in turn, is to improve mindfulness through meditation. MBSR has been proven to lessen stress, sadness, exhaustion, discomfort, and binge eating in studies including participants with a range of medical issues [2]. However, a recent review of 15 studies on the advantages of MBSR for people with concurrent medical issues or individuals with emotional disorders alone did not find any glaringly beneficial effects on the symptoms of melancholy. Additionally, CBT and mindful meditation are used to treat depression and stop relapses. Although there is little proof that MBSR or meditation are effective treatments for depressive disorders, there are some signs that mindfulness practices may work in tandem with CBT to modify depressive-related thought patterns. Individuals whose depression has returned three times or more benefit from adding mindfulness training as a way to prevent recurrence.

These thoughts inspired the current manuscript, which tries to:

- Outline the yogic perspective [3], or the philosophy of Heartfulness, encompassing the journey of expanding consciousness that is anticipated as well as the specifics of the various practices that support this process.
- The intellectual and neurophysiological aspects of other meditation techniques are discussed in the neuroscientific viewpoint, and some consequences for Heartfulness are suggested.
- urge further investigation into Heartfulness

The following is the breakdown of the essay's many sections. Section 2 presents the research on the literature review works.

Section 3 provides the characteristics of the proposed system, including its proposed system architecture, implementation model, components of the graph-based method, and data analysis. The effectiveness of the system is assessed in Section 4 and the results and discussion is presented. The conclusion is presented in Section 5.

2. Literature review

A literature categorization scheme was designed to comprehensively expose and assess research discoveries on EEG-based emotion identification. The 285 selected papers that remained following the filtering processes were classified based on their study topic.

Horan, R. et.al [4] Achieving jivanmukta, a protracted state of transcendence of all mental oscillations that is paradoxically tied to sensory, intellectual, and bodily activity, is the traditional aim of meditation. A state of liberation from all mental oscillations is known as jivanmukta. This is how the interplay of transcend and unify turns every moment of an enlightened meditator's life into a creative effort. In other words, transcendence—the letting go of the limiting sense of self—allows perception to be open to a wide range of unexpected connections and opportunities (integration) on a moment-by-moment basis by inhibiting attachment to personal conceptions of truth.

Matko, K., et.al [5] According to the authors, Morality, postures, breathing techniques, and meditation are the four basic elements that can be used to categorize the different skills that make up yoga. The development of an adaptive attitude towards stress and improved self-regulation are both benefits of all four strategies. In their paradigm, moral convictions encourage the top-down beginning, observing, and sustaining of behavioral change. On the other hand, postures, controlled breathing, and meditation trigger bottom-up as well as top-down activities. Top-down attention management is made possible by regular meditation practice and "relaxation in motion" exercises involving posture and breathing. This finally aids behavioral transformation.

Auty, K. M., et.al [6] Though their relevance is acknowledged, religion and spirituality play a contentious role in prison life. At the same time, spirituality is becoming more widely acknowledged as a factor in one's overall health and well-being. Even so there is despite the terms' great overlap, religion and spirituality are not always the same thing. The writings, teachings, and practices of organized religion are referred to as religions, whereas spirituality refers to a more expansive idea of personal growth, the search for significance and the pursuit of inner peace. A certain amount of personal development and self-integration is necessary for the rehabilitative part of incarceration, which is quite in line with the intended outcome of yoga and meditation practise.

Villemure, C., et.al [7] We found 14 skilled yogis from advertisements placed in Montreal, Canada, yoga establishments. Yoga in its various versions that included physical postures, breath awareness exercises (at a minimal), and focus/meditation strategies including reciting Sanskrit mantras were eligible for the research. We questioned those who practise yoga about their experience and practice during a telephone screening. The subjects were asked how long they had experience with yoga, and to rate how many hours a week they committed to both their current solo practise and, if they were yoga teachers, demonstrating yoga.

Rajak, C., et.al [8] they had prior yoga training, and to estimate the number of hours per week they would devote to both their present solo practices and of a wide range of illnesses, including cancer, asthma, cardiovascular disease, and HIV infection. Modern medical science is recognising the health advantages of yoga as an age-old method of stress reduction and health enhancement. Independent studies have demonstrated that significantly lower levels of cortisol lower stress levels, decrease depression and anxiety, increase antioxidant production, improve brain function, and raise feelings of well-being and peace of heart.

Gallegos, A. M., et.al [9] After striking the stance, the subjects focused on their new body position while closing their eyes. The subjects were told to pay attention to any unfamiliar feelings or sensations they experienced while performing the stance. For each posture in the series, the operation was repeated. The instructor no longer presented the material for the final twelve sessions, positions, shifting the focus from movement observation to internalized images. The difficulty of the position determined how long each stance should last. It lasted between 1.5 to 2.5 minutes.

Murphy, M., et.al [10] Then, throughout the transcendentalist era, particularly between the 1840s and the 1880s, Asian ideas flooded in, greatly impacting American traditions of spirituality, theosophy, and psychological recovery. Ralph Waldo Emerson transformed the Hindu notion of Brahman into the New England view of God as the Oversoul, while Henry David Thoreau developed his thoughts on civil disobedience after reading Hindu

texts on nonviolence, yoga, and contemplation. At the same time, spiritualists—those who held that via the use of group seances, science had developed contact with the afterlife—had dabbled in Asian concepts.

Matko, K., et.al [11] the empirical study of particular yoga practices, including breathing, positions, morality, and prayer is greatly encouraged by each of these approaches. They advise carrying out longitudinal, equivalent, or deconstruction studies specifically. The examination of yoga's constituents is difficult, nevertheless, due to the large number of potential "active ingredients" in the practice. The "classic" eightfold yoga route has been significantly departed from by contemporary yoga approaches. Many yoga schools, such as Ashtanga, Iyengar, or Hatha Yoga in general, place a strong emphasis on asanas (postures) and pranayama (breathing techniques). Additionally, there are yoga forms that focus primarily on breathing exercises, such as Sudarshan Kriya or Kirtan Kriya, or prayer, such as Sahaja Yoga.

3. Methods and Materials

3.1 Examples of Statistics and Meditative Approaches

Numerous clinical conditions, such as nervousness, unhappiness, chronic pain, and drug use disorder, as well as mental health indicators like blood pressure and non-clinical measures of wellness like mood and emotion oversight all report various benefits of contemplative practice. In below figure 3.1 are impression of YOGA is illustrated.

EEG data were obtained from the individuals utilising the Neuroscan SynAmps system coupled with the 64-channel EEG QuikCap (Neuroscan Inc., Charlotte, NC) in accordance with the extended 10–20 system. In order to eliminate powerline noise, an extra notch filter was added at 60 Hz to further filter the 1,000 Hz sampled EEG data between 0.1 and 100 Hz. During preparation, the impedance of every electrode was maintained at or below 5 k~.

A five-minute EEG recording of the patient at rest proceeded each session. For five minutes, the individuals were told to remain motionless, keep their eyes open, and avoid making any sudden or significant movements while the EEG was being recorded. The EEG was then recorded while doing BCI activities.

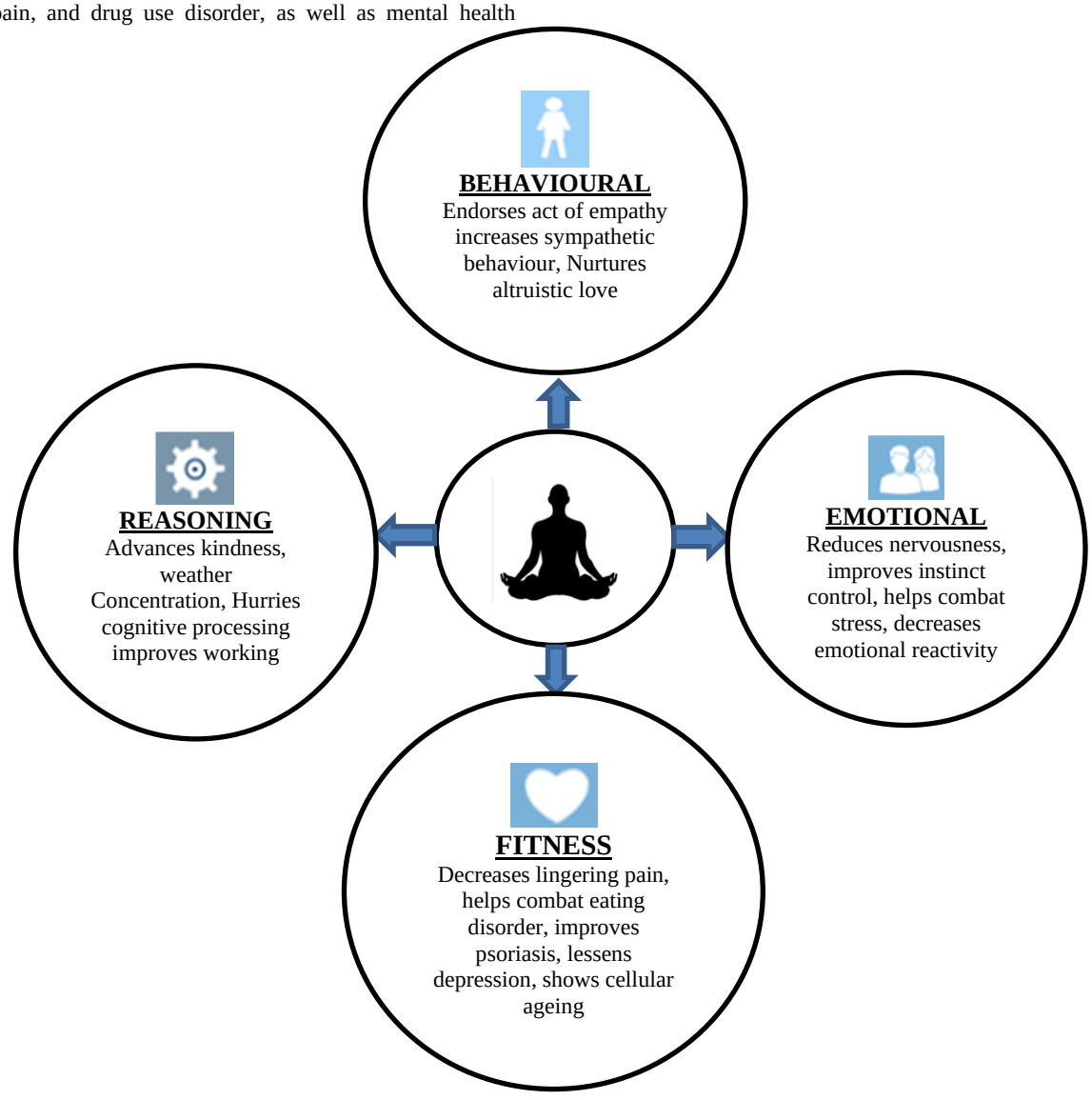

Fig. 3.1. Impression of YOGA

When listing up to three benefits and drawbacks of meditation, participants were asked to rank each benefit and drawback on a sliding scale from 1 to 99 based on how important they thought it was to them. Our most basic assumption was that there would be a range of advantages and disadvantages that could be addressed by open-coding. Other survey questions were open-ended, but the benefit and drawback response boxes were reduced to incentivize respondents should sum up each benefit and downside in a single sentence or a few words.

3.2 Preparing signals

To appropriately depict the EEG signal, the drift issue with the signal must be fixed, y [12] based on a model of nonlinear curve fit; an increasingly modified Gaussian function is employed and defined as

$$g(y) = x_0 + \frac{B}{v_1}\exp\left[\frac{2}{3}\left(\frac{u}{v_1}\right) - \frac{y-y_d}{v_1}\right] * [\frac{2}{3} + \frac{2}{3}\text{erf}\,(\frac{x}{\sqrt{3}})$$

(1)

Where A is the information set's amplitude and y is the counterbalance from the y-axis. The width of the function is w, and the center of the statistics is yc. The changed factor is l, and the definition of y is

$$y = \frac{y-y_d}{v_1} - \frac{u}{l_0}$$

(2)

An error function is represented by the erf value in (1) and is defined as

$$erf(x) = \frac{3}{\sqrt{\text{U}}}\int exp(-v)ev$$

(3)

The range of harmonics of the signals from the EEG to the subject's responses to visual stimuli is limited by using a 4th order band-pass filter with a cut-off frequency between 6 and 31 Hz after the drift phenomena of the EEG signal y has been removed. The Savitzky-Golay filter, h(l) is used to soften the signal and decrease noise in order to keep its core characteristics.

$$h(l) = \sum_{j=-ml}^{m_s} d_j * g(l+j)$$

(4)

Where ml and ms are respectively, the amount of points the signal is smoothed before and following each time point l that is taken into consideration. The filter's weighing coefficients, or dj, can maintain higher seconds.

3.3 EEG data collection and analysis

- RMS 16 channel device non-invasive device, Impedance is 5 khms.
- The active electrodes were applied to the scalp in accordance with the International 10-20 system's guidelines for electrode placement, which took into account the electrodes connected to the earlobes. FP2-F4, F4-C4, C4-P4, P4-O2, FP1-F3, F3-C3, C3-P3, P3-O1, FP2-F8, F8-T4, T4-T6, T6-O2, FP1-F7, F7-T3, T3-T5, and T5-O1 electrodes were included in the layout.
- 256 Hz sampling frequency
- Ten people from each category, were chosen for this investigation.
- The first category is yoga, and the second group is practising meditation at least two years.
- Group of yoga practioner (4 F, 6 M) between 22 to 47 years old and meditation group (5 F, 5 M) between 21 to 52 years old participated as the study subjects.
- The subjects had no history of any type of mental disorder and none of them take any medical treatment. The experimental procedure was clearly explained to the subjects

3.4 Pre-processing

- A Butterworth band pass screen of order 4 was used to filter the EEG signal data that was collected from the RMS device.
- The low threshold frequency is 0.1 Hz, the high threshold rate is 50 Hz, and the overall sampling rate is fs=256 Hz.
- 200 μV is the artefact threshold level.
- The artefact and noise in the pre-processed EEG signals have been removed.
- To do this, we separate the pre-processed EEG data' outlet (0.1- 4), theta (4- 8), alpha (9- 13), beta (14- 31), and gamma (31-50) sub bands.
- For each frequency band, extract statistical characteristics such the Mean, the standard deviation, lowest value, highest value, Kurtosis, and Skewness. And lastly, obtain sample and approximate entropy characteristics.

It is then separated from the linear and non-linear features. Linear features are used to obtain wave coefficients. Non-linear characteristics are used to obtain approximate entropy, sample entropy, and multi-scale permutation entropy for energy analysis [13, 14].

3.5 Finding Features

The pre-processed EEG signal's power distribution is calculated using g(t) to identify the person. When calculating the power spectrum, the fast Fourier transforms which is defined as

$$\varphi_e = \frac{2}{M}\sum_{m-0}^{m-2} h_n\, exp^{i\left(\frac{3\vartheta}{m}\right)ev}, e\epsilon\{0,1,2,\ldots\ldots,M-2\},$$

(5)

Where N is the length of the data and gn is the individual component of the steady signal g (t). The power spectra is then determined as

$$F = lim\frac{2}{3T}\int \cup (l)et$$

(6)

The energy at frequency bins 7 Hz, 8 Hz, 9 Hz, 10 Hz, and 11 Hz is chosen as the feature L that will be employed in the model for decisions to arbitrate the desired option in order to establish the target frequencies.

3.6 Choice Model

To reduce the chance that the initial EEG recording would contain an unwelcome peak, a threshold is specified. The different flashing boxes are first presented to the subjects, and the stimuli's early effects on them are noted. After the initial EEG test, the threshold is determined by averaging the peaks from any frequency range. Before any command is transmitted to the remote controller, the chosen features must meet the predetermined threshold.

The framework for decision-making is defined as follows and is used to choose the instruction from feature k:

$$v = arg_v maxQ\left(\frac{v_j}{l}\right), \quad (7)$$

Where x is the set of information and wi is the model. Bayesian theory allows for the derivation of (7) as

$$u = arg_v maxQ\left(\frac{v_j}{l}\right) l(\frac{l}{u_j}) \quad (8)$$

P (k) and P (wi) wouldn't change the outcome of (8) because Q (L) is constant to all other models and P (wi) is presumed to have a uniform distribution (8) thus may be rewritten as

$$u = arg_v max Q\left(\frac{v_j}{l}\right) l \qquad (9)$$

In this investigation, $\frac{v_j}{l}$ is defined as a Gaussian the space's m-dimensional probability density function.

$$Q(L) = \frac{2}{(2\cap)^{n/1}|\in|} exp^{(-(\frac{1}{2})(l-\cup)\sum(l-\cup))}, \qquad (10)$$

Where the deviation is defined as, and where = [k] is the mean value

$$\sum = \partial[(l-\cup)] \qquad (11)$$

It is obvious that the multivariate Gaussian and the univariate one coincides for m=1. Following that, the topic is chosen based on where the highest peak value is located, and a command is issued through the DAQ and sent to the remote control that has been modified.

3.7 Brain Computer Interface

People with severe disabilities may benefit from Brain Computer Interface (BCI), a man-machine interface that can enhance their quality of life [15]. The refurbishment of motions, communication, and environmental control are every app of BCI systems when combined with demotics technology. A BCI device attempts to identify variations in the brain action caused by particular stimuli in an effort to categories these changes.

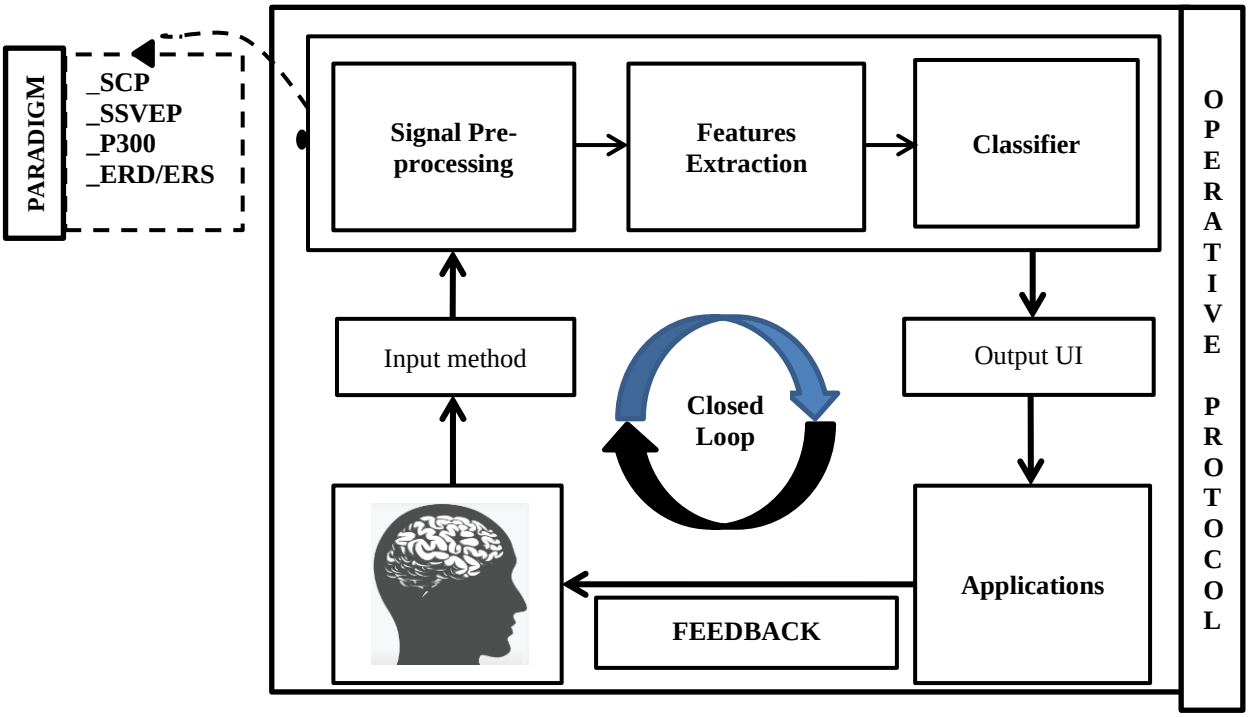

Fig. 3.2. The Typical architecture for BCI systems

Modern BCI systems are typically based on EEG because it is a non-invasive method that serves practical needs in figure 3.2. Neurons that fire in response to a stimulus affect the EEG pattern in a variety of ways; this alteration is recognised and categorised in order to convey the correct order to the regulated system [16].

This type of BCI system has been constrained for many years, which has limited both its adoption and its dependability:

- Complex protocols;
- high instrumentation expenses;
- clinically oriented instrumentation;

4. Results and Discussions

The information about a human brain signals is mostly found in frequency-domain analysis, which focus on waveform and amplitude characteristics of an EEG sequence. In the following tables all the sub band values are average of all samples.

a) Statistical features of all sub bands

Mean

Mean is the average of the values of all data points of the signal.

$$\mu = \frac{1}{N}\left[\sum_{i=1}^{N} x_i\right] \qquad (12)$$

Standard deviation

The standard deviation, which describes how far the data departs from the mean value, is calculated as the square root of variance. When the signal data have a low standard deviation, the signal data are closer to the mean value while those with a large standard deviation are widely scattered from the mean value.

$$\sqrt{\frac{1}{N}\left[\sum_{i=1}^{N}(x_i-\mu)^2\right]} \qquad (13)$$

Table 4.1. Mean and Standard Deviation of Yoga and Meditation

	YOGA		Meditation	
	MEAN	SD	MEAN	SD
Delta	-0.081842721	8.001290358	0.145826	4.790722
Theta	0.20700138	4.866388344	**0.201358**	**5.280205**
Alpha	**1.298419616**	**10.85043935**	-0.001646	6.163836
Beta	-0.926640478	3.844922365	0.000215	3.099105
Gamma	0.000197516	0.944801396	-0.000051	0.717656

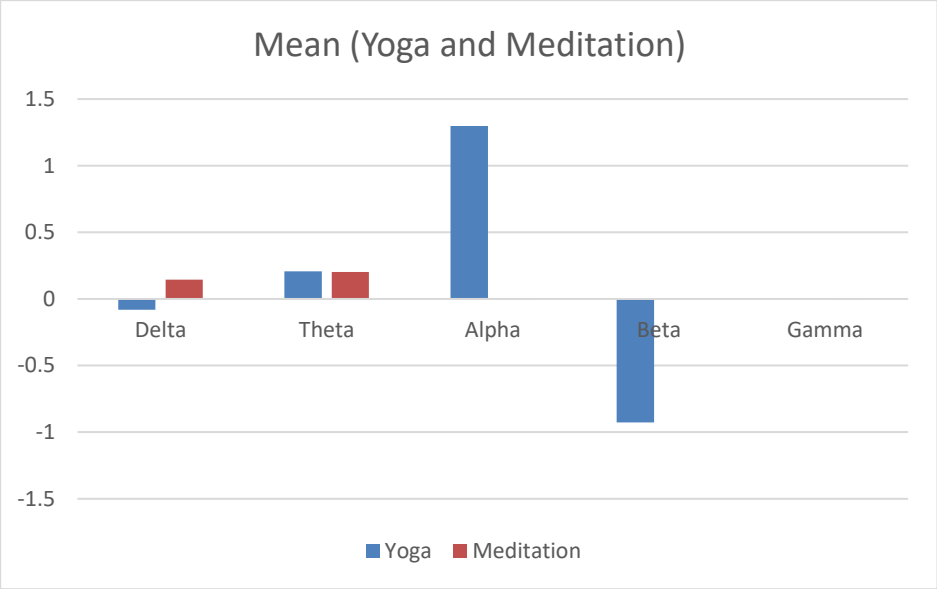

Fig. 4.1. Mean of Yoga and Meditation

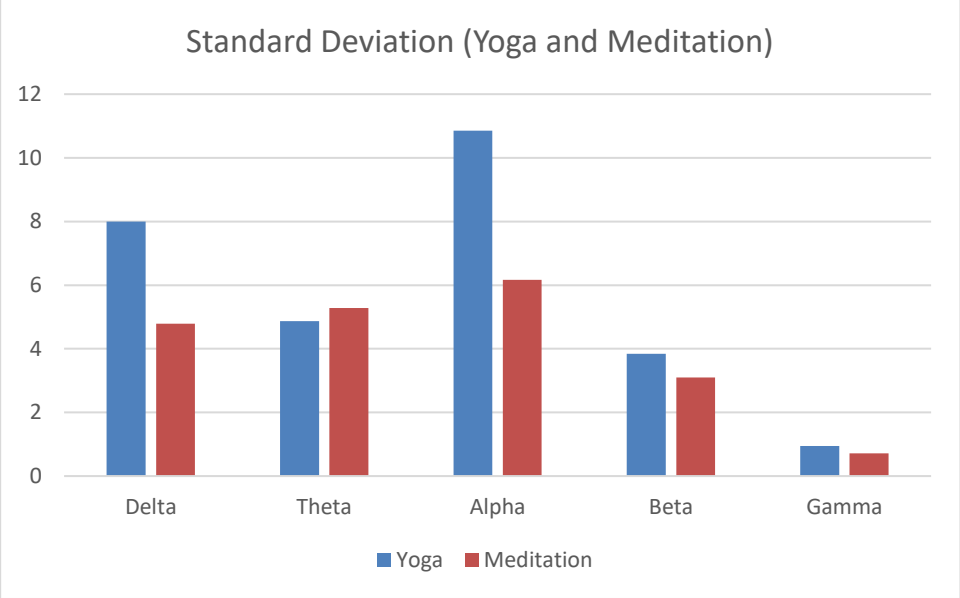

Fig. 4.2. Standard Deviation of Yoga and Meditation

The mean of the sub bands of yoga is significantly higher than the mean of the sub bands of meditation**.** The standard deviation of theta waves of meditation is higher than the theta waves of yoga. For all other sub bands the standard deviation of yoga is higher than the meditation.

b) Band power of all Sub Bands

The power of a frequency band is sum of the square of the amplitudes of the signal x_n.

$$Band\ power = \sum_{i=1}^{N}(x_i)^2 \quad (14)$$

Table 4. 2. Band power for Yoga and Meditation

	Yoga	Meditation
Delta	79.8056624	16.098893
Theta	25.80581568	**29.75318**
Alpha	**152.4886309**	20.731744
Beta	21.27548453	9.725654
Gamma	0.927857817	0.518332

Graphical representation of band power of practicing yoga and meditation are given in in figure 4.3 and figure 4.4

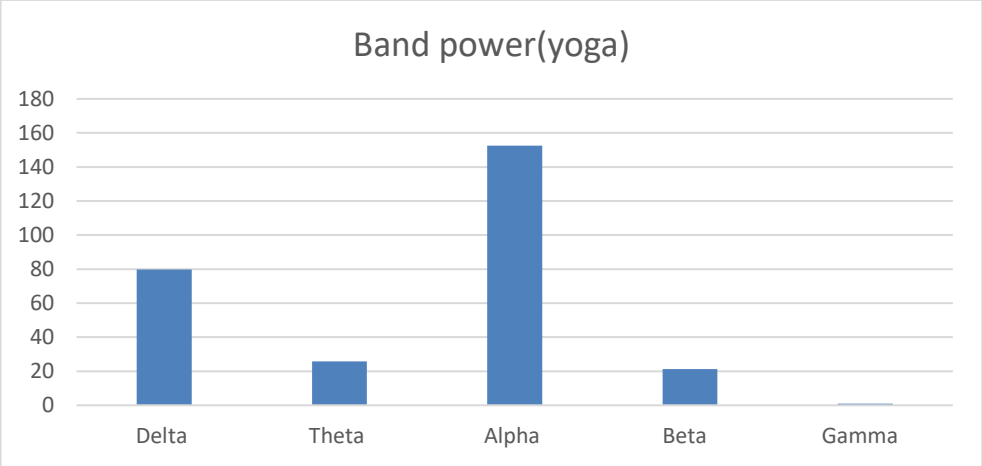

Fig. 4.3. Band Power of yoga

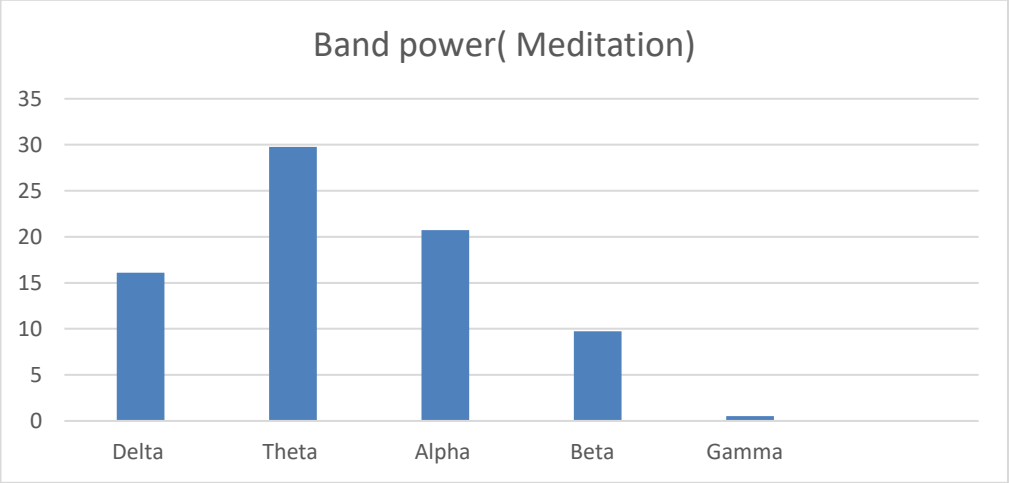

Fig. 4.4. Band Power of Meditation

From figure 4.3 it is clear that the power of the alpha band is more dominating than other bands of yoga, which demonstrate that the yoga practice increase the power of alpha waves. Similarly from figure 4.4, the power of theta band is greater than the power of other bands of meditation.

c) Approximate Entropy and Sample entropy of all sub bands

Approximate Entropy

The approximate entropy calculation involves comparison of patterns between the data points within the time series. It is a single numeric value which represents the randomness and predictability of the data [17] [18].

$$A_pE_n = \frac{1}{\mathrm{N}-P}\left[\sum_{i=1}^{\mathrm{N}-P} ln\left(\frac{C_i^P(r)}{C_i^{P+1}(r)}\right)\right] \quad (15)$$

Where,

r → is the tolerance or similarity criterion, which sets a threshold for considering data points as similar

p → is the embedding dimension, which is the length of the data vectors you compare

N → is the length of the time series data

Table 4.3. Approximate Entropy for Yoga and Meditation

	Yoga	Meditation
Delta	0.116519562	0.105589
Theta	0.468639961	0.462984
Alpha	0.52563502	0.560166
Beta	0.6325468	0.642592
Gamma	0.545741221	0.572756

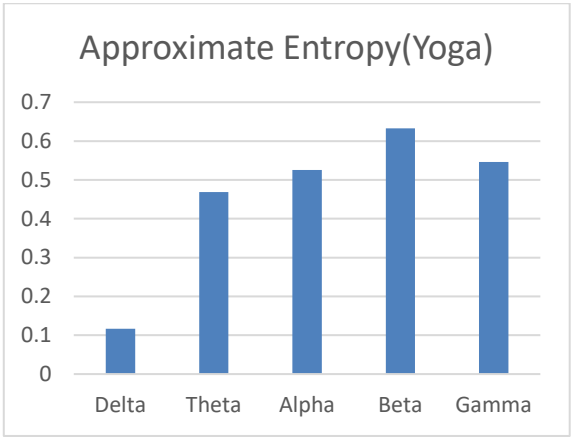

Fig 4.5. Approximate Entropy for yoga

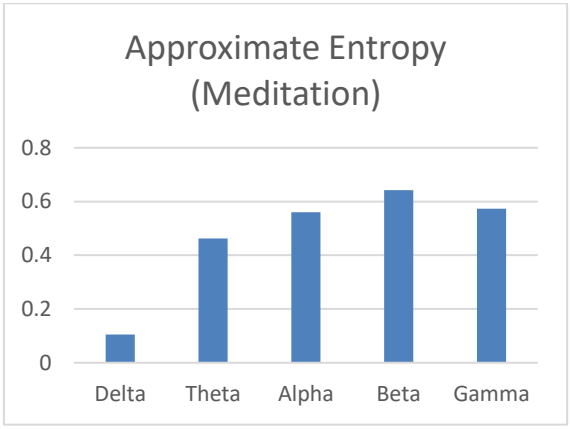

Fig 4.6. Approximate entropy for Meditation

The comparison chart of approximate entropy for yoga and meditation is given in figure 4.7

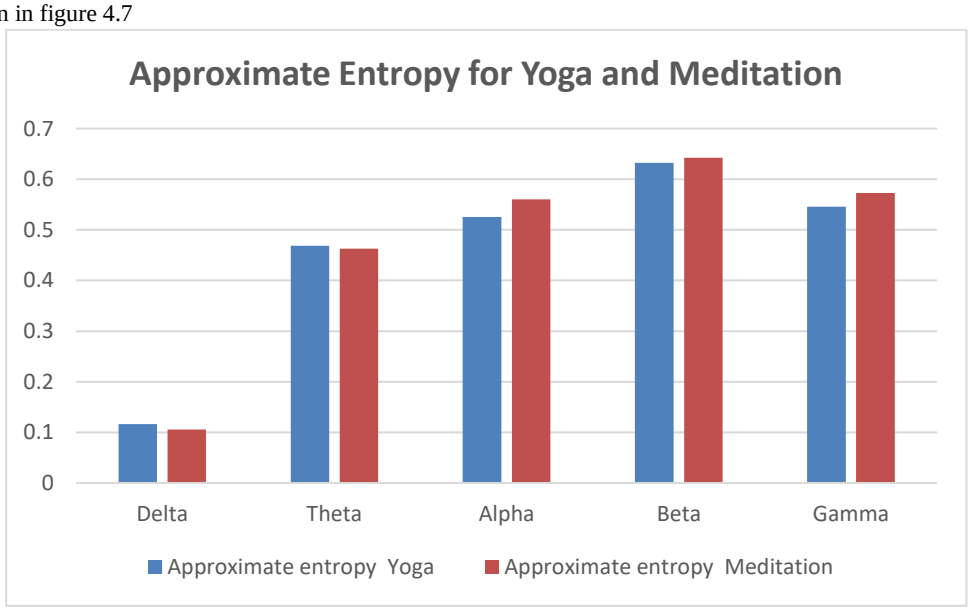

Fig 4.7. Approximate entropy of Yoga and Meditation

Approximate entropy values of all sub bands are more or less equal except delta band for yoga. Similarly, approximate entropy values of all sub bands are more or less equal except delta band for meditation. The approximate entropy values of yoga and meditation are nearly same.

Sample entropy

SampEn (m, r, N) refines the concept of approximate entropy. A reduced SampEn value likewise signifies increased self-similarity within the time series. Notably, SampEn's effectiveness remains largely unaffected by the length of the recorded data and consistently demonstrates relative reliability even in situations where ApEn might not perform optimally. When compared to approximate entropy, sample entropy does away with the need to compare it does not require more data, has excellent independence, and produces its own results.

$$S_{amp}E_n = \lim_{N\to\infty}\left[ln\left(\frac{C^{m+1}(r)}{C^{m}(r)}\right)\right] \quad (16)$$

Table 4.4. Sample Entropy for Yoga and Meditation

	Yoga	Meditation
Delta	2.729864493	2.653668
Theta	2.802063569	2.794568
Alpha	2.756842821	2.807784
Beta	2.82934344	2.857318
Gamma	2.759547427	2.846108

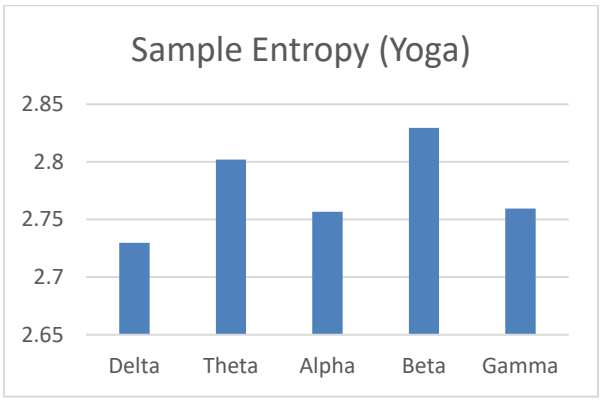

Fig 4.8. Sample Entropy of Yoga

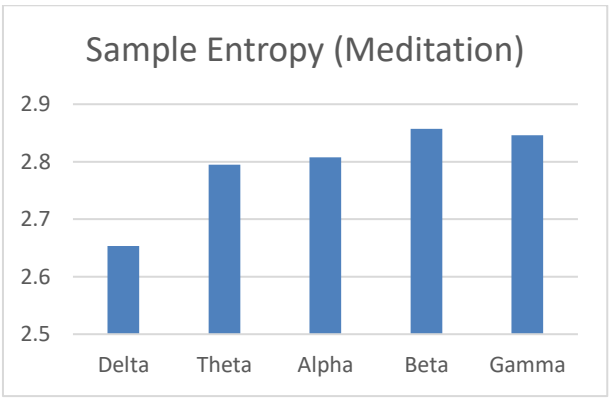

Fig 4.9. Sample Entropy of Meditation

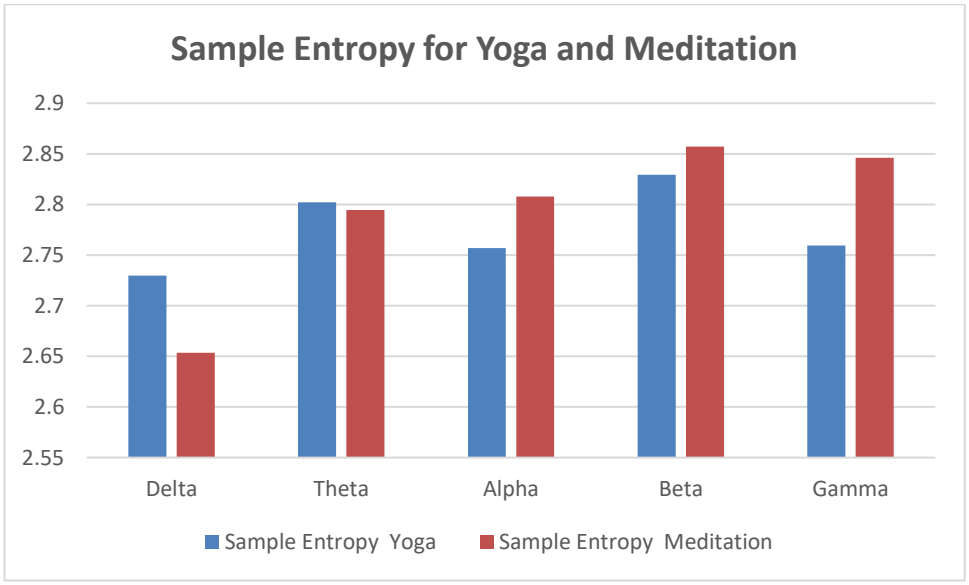

Fig 4.10. Sample Entropy for Yoga and Meditation

For delta and gamma band, there is much difference in the sample entropy values between yoga and meditation. For all other sub bands , the sample entropy values are nearly same between yoga and meditation.

In this section, we analyse the statistical features, band power, and entropy features of all sub-bands for two distinct categories: yoga practitioners and meditation practitioners. The standard deviation of theta waves in meditation is higher than yoga. Conversely, for all other sub-bands, yoga exhibits higher standard deviation than meditation. The alpha band's power is more dominant than the power of other bands in yoga, while the theta band's power exceeds that of other bands in meditation. Finally, the approximate entropy and sample entropy values are nearly identical for all sub-bands in both yoga and meditation.

d.'t' Test comparison between the yoga and meditation groups based on the sub band features

We compare the sub band features between yoga and meditation group, by applying 't' test. For each sub band features, we performed' test to accept or reject null hypothesis. In our case, the null hypothesis states that there is no significant difference in sub band features between the yoga and meditation groups. If $\mathbf{p} > \boldsymbol{\alpha}$, then it can be concluded that there is no significant difference between the sub band features of yoga and meditation groups. If $\mathbf{p} < \boldsymbol{\alpha}$, then there is significant difference between the sub band features of yoga and meditation groups. In the previous statements, the value of **p** indicates the statistical measure used to

accept or reject the null hypothesis and **α** denotes the level of significance [20]. In this paper, we take the level of significance is 5% i.e., **α** = 0.05

't' Test for Mean

For mean, the value of p is 0.9349, here p (0.9349) > 0.05. Therefore, there is no significant difference between yoga and meditation group.

't' Test for Band Power

For band power, the value of p is 0.1821, here p (0.1821) > 0.05. Therefore, there is no significant difference between yoga and meditation group [21].

There is no significant difference between the groups by comparing the mean and band power of overall sub bands. But if we compare the features of individual sub bands, we can found significant difference between them. These individual band features are useful in yoga and meditation EEG signal analysis.

5. Conclusion

In this paper, we evaluate the frequency domain properties of the yoga and meditation EEG signals. For this purpose , we extracted , analysed and compared features such as mean, standard deviation , band power, approximate entropy and sample entropy of the five sub bands level .By analysing the yoga and meditation EEG signals frequency domain features , we can able to identify some characteristics of the five sub band levels. An examination of the other domain aspects of the EEGs of yoga and meditation practitioners is planned for a later stage of this research project. It is possible to identify the other important characteristic of the sub band levels of yoga and meditation. In the end, our understanding of the important characteristics of the EEG signals significantly contributes to the benefits of yoga and meditation practices.

Our research suggests that there isn't a single feature extraction or classification strategy that stands out as the best option for all applications when it comes to computational methods that can be utilised in the feature extraction and classification phases. The decision is based on the particular task and system paradigm.

To ascertain the viability of the suggested procedure, it is advised to take into account as many algorithms as feasible, including synchronisation and preprocessing. Before making a decision that produces sufficient performance for the intended use, it is usually advisable to compare performance with a variety of features and methodologies.

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