ISSN: 2319-6505

Available Online at http://journalijcar.org

International Journal of Current Advanced Research
Vol 5, Issue 5, pp 895-899, May 2016

International Journal of Current Advanced Research

ISSN: 2319 - 6475

RESEARCH ARTICLE

IMPACT OF MEDITATION ON AGE RELATED BRAIN- DEGENERATION

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ARTICLE INFO

Article History:

Received 26th February, 2016
Received in revised form 17th March, 2016
Accepted 25th April, 2016
Published online 28th May, 2016

Key words:

EEG, Functional Connectivity, Graph Theory, Local and Global Efficiency, Neuro-Degeneration

ABSTRACT

A rapid advancement in age population gives rise to the need to overcome losses cause by ageing. Normal ageing not only affects the processing power of the brain but also associated with significant losses of brain tissues. Here, graph theory could play an important role for accurate diagnosis, by detecting change in clustering and topology of the brain networks due to disease and ageing factor. In neuro-imageing data of ageing graph theory parameters can easily measure out degeneration occur in the brain by analyzing change in structural and functional connectivity of brain. Rate of neuro-degeneration and cognitive decline in brain can be decrease by practicing meditation on regular basis. Meditation can also be a remedy to decrease anxiety and daily stress which are the main cause of brain-degeneration. In the present study on resting state EEG data of 34 subjects (20-50 years) functional connectivity of the brain has been analyzed in alpha and theta band accompanied with local and global efficiency of brain networks. The main focus of this study was on positive effects of meditation to compare the degeneration occurring in normal individual and a long term meditator due to ageing. Analysis by ANCOVA shows meditation as an effective practice to reduce effects of ageing. Motif number, path length, clustering coefficients, local and global efficiency are the quantifiers of functional connectivity, in which global efficiency find to be increased in theta band along with increase in motif number of the meditators as compared to controlled subjects whereas local efficiency of the meditators subjects nearly find to be same as young groups of the controlled subjects. Moreover, the global efficiency of the controlled subjects find to be increased in alpha band when compare with meditators.

INTRODUCTION

The world's population ageing rapidly by 2050 it is expected that 16 percent of world's population would be 65 or older. So, Healthy ageing, is defined as failure of replacement of cells in sufficient number to maintain full functional capacity in psychological and physiological aspect. Ageing on one hand holds experience and satisfaction in society on the other hand is accompanied by decline in neural structure and activity of the brain. 25 percent reduction in overall brain electrical activity, probably related to decreased blood flow as we age which results in decreasing brain density and weight specifically in the frontal and temporal lobe volumes. (Stephen F. Barnes, (2010) [2]).

In recent research on ageing meditation could be seen as beneficial method to decrease the ill effects of ageing. Meditation seems to be based on civilizations and culture for some it is a means of relaxation and peace while for others a way for spiritual growth in religion. Meditation is a practice of concentration upon an object. The object of concentration may be internal or from outside environment. Meditation has different forms exist and defined in different ways. (Newberg *et al* (2013) [3]), define meditation as a means of "focused attention" to regulate attention. (Lazar *et al* (2005) [10]) find cortical thickness in areas associated with attention, interoception, and sensory processing. (Slagter *et al* (2011) [18]) associate meditation as control over distributed brain resources. (Luders *et al* (2015) [12]) associate age-related gray matter atrophy in meditation practitioners. In which he focused on link between age and cerebral gray matter. (Gard *et al* (2013) [5]) studied potential effects of meditation on age-related cognitive decline. In which they suggest that meditation interventions are feasible for older adults. (Pagnoni *et al* (2007) [14]) studies the effects of age on gray matter volume and attention performance in Zen meditation.

Their findings suggest that regular practice of meditation may have neuroprotective effects and reduced cognitive decline, associated with normal ageing. A review of age-related brain degeneration is done by (Luders *et al* (2014) [11]). The outcomes from all the studies and review suggested that meditation may slows down or even reverse age-related brain degeneration.

To further expand this field of research, we assume to examine the link between the brain degeneration due to aging and impact of meditation on it using the approach of functional connectivity. To test this assumption study was done on a sample of 34 subjects (12 meditators (30-50 yrs)/12 controls (30-50 yrs)/10 controls (20-30 yrs)). For this study EEG data has been collected by using 14 channels Emotiv test bench. Firstly phase synchronization has been calculated to find out the functional connectivity of the subject. Phase synchronization has demonstrated to be effective in inferring neural connectivity, especially when the connectivity is too weak to be detected by other measures (Pikovsky *et al* (2001) [15]). The functional connectivity matrix obtained is use for calculating the local and global efficiency.

The topological organization of a network is directly related to its local and global efficiency, which jointly determine the network's capability of integrating information effectively (Sporns (2012) [1]). Local efficiency is a measure of the average efficiency of information transfer within local subgraphs or neighborhoods and is defined as the inverse of the shortest average path length of all neighbors of a given node among themselves (Latora V, Marchiori M (2001) [9]). Degree of segregation of information processing persists in the brain networks due to aging is the significance of local efficiency.

Global efficiency is a measure of the efficiency of distant information transfer in a network and is defined as the inverse of the average characteristic path length between all nodes in the network (Latora V, Marchiori M (2001) [9]). Capacity for integrated processing and parallel information transfer in the brain due to aging is the significance of global efficiency. Motifs are small local connection pattern, which act as functional meaningful building blocks of a network and, therefore, is considerable for being useful for understanding design principles and functioning of networks.

Motif detection has been directly adopted into a variety of research fields; interesting results have been obtained by its application to study structural-functional relationships in networks from various domains such as protein-protein interaction networks, the World Wide Web, electronic circuits, synaptic neuronal networks, and transcriptional gene regulation networks (Schmidt *et al* (2012)[17]). Motif detection involves estimating the occurrence of each subnetwork of size k (sub network induced by vertex set of k vertices) (Wernicke (2005) [24]) and determining graph isomorphism for grouping found in subnetworks into equivalent classes (Foggia *et al* (2001) [4]).

Functional connectivity matrix obtain from phase synchronization has been used for finding out frequency of functional motif. Frequency of functional motifs contains number of interconnections of size k present in all possible equivalent classes. In order to identify the number of connection patterns in brain network the functional motif of order 3 has been used. For the present sample of data we have expected the results favoring meditation on all the functional measures of the graph theory assume to be calculated on present study of meditation altering the effects of aging. Meditation assumes to be capable in reducing the degeneration caused in brain due to aging.

MATERIALS AND METHODS

The present study directly follows up on commercial EMOTIV EPOC wireless EEG headset with 14 channels which gives a measure of the electrical activity on the cortical surface of the brain.

Participants and data acquisition

Twenty two healthy control subjects (Mage = 23 years, SD = 2.64, age range: 20–30 years) who never practiced meditation and twelve meditators (Mage = 39 years, SD = 5.62, age range: 30–50 years) with more than 10 years of daily practice have participated in this study, whose EEG data have been recorded continuously using Emotiv in EDF (European data format) at 128 Hz in resting state.

MEDITATION METHODOLOGY

All the experimental subjects are the practioner's of meditation. All meditators are the proficient of Rajyoga meditation. The practice involved two phases, Concentration exercises, often using an object such as a flower or a candle, and the repetition of a mantra. A mantra is a sacred phrase, word or sound which is repeated constantly, either loudly, silently or in thoughts only. Raj Yoga meditation does involve concentration, but no physical object is involved. The object of concentration is the 'inner' self. Instead of repeating one word or phrase, as in a mantra, a flow of thoughts is encouraged, thus using the mind in a natural way.

EEG Analysis

Only the baseline of 5 second is considered for this study in both the age groups. The electrodes are located to important regions of information processing (frontal, occipital and parietal brain regions) in the brain. Eye movements are considered as the artifacts and are removed by preprocessing of data using ICA (independent component analysis) in EEG lab. Then data was decomposed into two frequency bands, alpha (7-12 Hz) and theta (3-6 Hz) since signal power is mainly situated in this range, for further computation to be done.

Node wise functional brain networks are generated from a phase synchronization matrix of time series EEG data. From each vertex pair the negative connections were not included in this analysis. Meditators and control participants have approximately the same number of nodes in all conditions, indicating that network measures between age cohorts are comparable. On the connection networks the network measures are calculated to measure out the effects of meditation in altering the ageing.

Network Metrics

Global Efficiency

For the means of information flow, efficiency is an appropriate method to describe brain networks. Efficiency is a more biologically relevant metric to describe brain networks from the perspective of information flow, which can deal with the disconnected graphs, nonsparse graphs or both (Latora and Marchiori, 2001; Bassett and Bullmore, 2006). Formally, global efficiency is calculated as:

$$\text{Eglobal} = \frac{1}{N(N-1)} \sum_{i,j \in N, i \neq j} \frac{1}{d_{i,j}}$$

Where N is the set of all nodes in the network and Lj, k is the average distance (number of steps) between nodes i and j in the network. Global efficiency varies from 0-1, with a value of 1 implies maximum global efficiency in the network. Global efficiency provides a measure of the overall capacity of parallel information transfer and integrated processing among distributed components of the brain network (Sporns. 2012). Importantly higher order cognition functions, such as working memory may require the integration of information from several disparate sources, benefiting from global efficiency across the entirely of the network.

Local Efficiency

Local efficiency measure the ability of a network to transmit information at the local level, respectively. Local efficiency is first computed for each individual node i in the network by identifying the set nodes, or subgraph, to which node i is directly connected. After removing node i from the identified subgraph, the shortest path between all nodes in the path between all nodes in the subgraph has been calculated.

The inverse of the shortest path from each node formerly connected to node i to every other node formerly connected to node i are then summed across all nodes formerly connected to node i and this summed quantity is normalized by taking into account the total possible number of connections that can exist among all nodes formerly connected to node i.

Formally, local efficiency is calculated as:

$$\text{Elocal} = \frac{1}{N}\sum_{i\in N} E(G_i)$$

Where N represents the number of nodes in the subgraph Gi. Local efficiency is a scaled measure ranging from 0–1, with a value of 1indicating maximum local efficiency in the network. In functional brain networks, high local efficiency suggests a topological organization indicative of segregated neural processing (Rosenblum *et al*., 2001). The local efficiency of the network is associated with information transfer through the network. Node having high value of local efficiency represents their effectiveness of information sharing with other neighbors in the network, which provides a basis of effective segregation of information processing in the network.

Motif

A functional motif only consists of the original M vertices, but only contains a subset of (M^2-M) edges. We viewed functional motifs as potential "processing modes" or effective circuits of the brain network. For each size M there is a limited set of distinct motif classes. In this paper, we consider only M=3(with Z Score 4.33), for which there are 13 distinct motif classes. Motif-number is the occurrence of the total number of motifs in a network, which gives the total number of interconnections possible in the brain network.

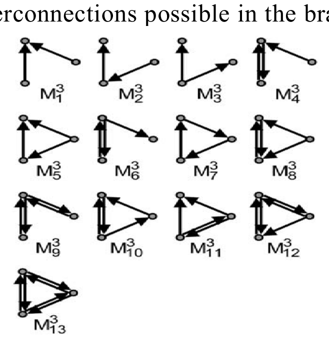

Figure 1 Possible Number of Motif-Classes of Order 3

Clustering Coefficients

It is the proportion of edges ei that exist between the neighbors of a particular node (i) relative to the total number of possible edges between neighbors (Bullmore and Sporns, 2009).

The equation for C at an individual node of degree ki is:

$$\text{Ci} = \frac{2ei}{ki(ki-1)}$$

The overall clustering in a network can be determined by averaging the clustering across all individual nodes. High clustering supports specialization as local collections of strongly interconnected nodes readily share information or resources.

Path Length

Path length (L) is a measure of the distance between nodes in the network, calculated as the mean of the shortest geodesic distances between all possible node pairs:

$$L = \frac{1}{N(N-1)}\sum_{ifn, i\neq j} dij$$

Where d_{ij} is the shortest geodesic distance between nodes i and j. Small values of L ensure that information or resources easily spreads throughout the network.

Statistical Analysis

We perform univariate Analysis of Covariance (ANCOVA) to control and meditators group for analyzing the effectiveness of meditation. This statistical model can assess effects of meditation on controlled groups, and allows the inclusion of weighted averages network efficiencies as a covariate.

Statistical analysis has done using IBM SPSS software.

RESULTS

All Statistical results are displayed in Table 1 regarding effects of meditation on controlled group. Using analysis of covariance significant differences are generated in local efficiency of alpha (P = 0.022 and F = 3.971) and theta band (P = 0.049 and F = 0.059), Clustering coefficients in theta band (P=0.038 and F= 0.046). And also in global efficiency of theta band (P = 0.0501 and F = 0.0281). However, no significant difference has been observed in local efficiency of theta band, clustering coefficients in alpha band and path length in alpha and theta band.

Table 1 P-Values of the Differences Associated with Meditators and Experimental (Young and Old Non-Meditators)

Property	Alpha Band	Theta Band
Local Efficiency	**0.022(*)**	0.085
Global Efficiency	**0.049(*)**	**0.0501(*)**
Clustering Coefficients	0.067	**0.038(*)**
Path length	0.071	0.0634

Numbers in the bold indicate significant differences between the group, Asterisk is defined as *<0.05

Graph Measures

Global Efficiency

Observing the link between global efficiency and connectivity we have observed the following the following changes occurred in the integrated processing of the brain due to ageing. The global efficiency changed as follows in alpha and theta band in experimental and meditators group:

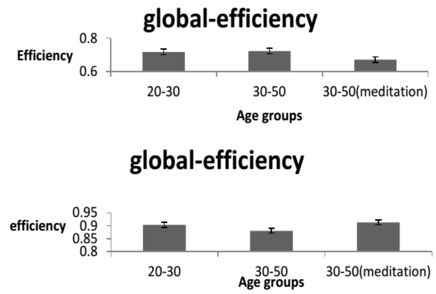

Figure 2 Global Efficiency in Alpha and Theta Band

Local Efficiency

When observing the local efficiency of each of the 14 channels the following changes are observed in both the experimental and controlled groups in alpha and theta band:

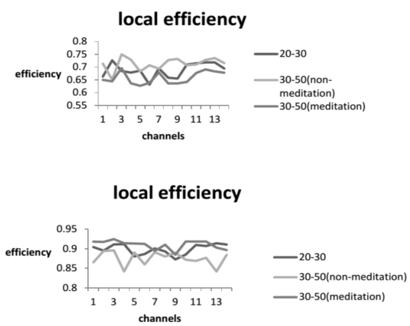

Figure 3 Local Efficiency in Alpha and Theta Band

Motif –Number

For the motif of order 3 following number of interconnections in all thirteen possible classes are observed for both controlled and meditators groups in alpha and theta band: Examining the link between ageing and meditation we have used descriptive statistics for significant analysis of differences.

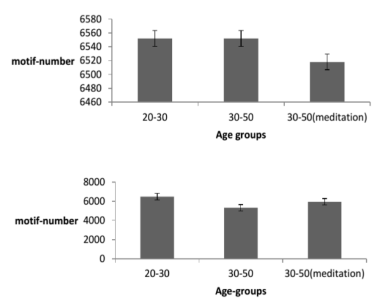

Figure 4 Motif-Numbers in Alpha and Theta Band

This test is carried out separately for all the values of meditator and both controlled groups. The difference is consider significant at $P<0.05$. For Statistical analysis, we use SPSS toolbox freely available.

Table 2 Graph Metrics of (20-30), (30-50) and (30-50) Meditation

	(20-30)yrs		(30-50)yrs		(30-50)meditation	
Graph metrics	Mean	SD	Mean	SD	Mean	SD
Local Efficiency	0.6884	0.02837	0.7132	0.02515	0.6583	0.02414
Global Efficiency	0.8107	0.13073	0.8019	0.11103	0.7920	0.17092

These tests are done to check the significant values of graph theoretical measures, for which the computation is done on the weighted averages of local efficiency and global efficiency.

CONCLUSION

In this study we have investigated age-related degeneration of brain by means of analyzing changes in network parameters calculated on connectivity metrics, for controlled and meditator subjects. Our hypothesis has been complemented by age-related decline in network connectivity of both controlled and meditator groups. The local efficiency and global efficiency shows the degree of segregation and integration in information processing of the brain networks. Lower local efficiency is accompanied by more resilience to network degeneration caused due to ageing. As brain degeneration is associated with the cognitive state of brain. Hence, improvement in the cognitive state of brain is impact of meditation on age related decline. So, healthy ageing could be accompanied by better working memory, attention and perception with positive effects of meditation on ageing.

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