CHARACTERISING AND COMPARING EEG SIGNATURES OF PERSEVERATIVE COGNITION FOR YOGA AND NON-YOGA PRACTITIONERS

Dissertation submitted by

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Under the guidance of

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Towards the partial fulfilment of

MASTER OF SCIENCE IN YOGA THERAPY

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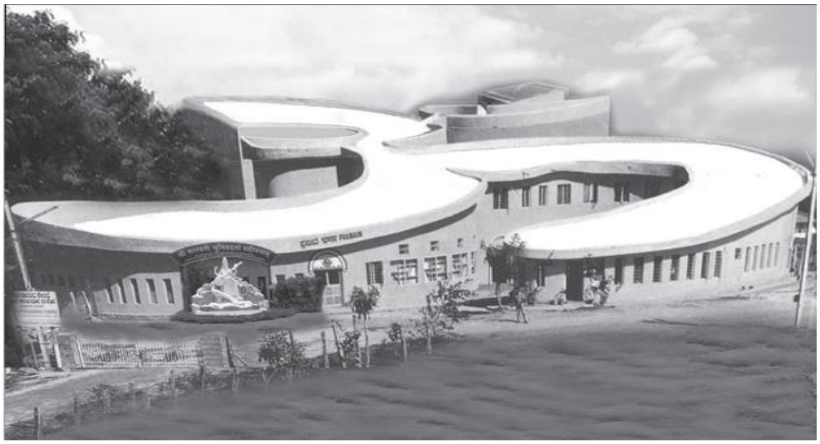

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CERTIFICATE

This is to certify that Krupa Virendra Thakkar who registered for the degree of Master of Science in Yoga Therapy at Swami Vivekananda Yoga Anusandhana Samsthana (S-VYASA University) Bengaluru, under the division of Yoga and Life Sciences, has completed the required training in acquiring the relevant knowledge of Yoga and Therapy and has successfully carried out the research project titled "Characterising and Comparing EEG Signatures of Perseverative Cognition For Yoga and Non-yoga Practitioners" in partial fulfilment of the course as per the regulation of the University.

Date:
Place: Bengaluru

Dr. B. Ragavendrasamy

DECLARATION

I, Krupa Virendra Thakkar, hereby declare that this study was conducted by me at Swami Vivekananda Yoga Anusandhana Samsthana (S-VYASA), Bangalore, under the guidance of B. Ragavendrasamy, Judu Ilavarasu & Rajesh SK of S-VYASA University, Bengaluru.

I also declare that the subject matter of my dissertation titled 'Characterising and Comparing EEG Signatures of Perseverative Cognition For Yoga and Non-yoga Practitioners' has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or similar titles.

Date: Krupa Virendra Thakkar
Place: Bengaluru

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STANDARD INTERNATIONAL TRANSLITERATION CODE USED TO TRANSLITERATE *SAṀSKṚTA* WORDS

अ	आ	इ	ई	उ	ऊ	ऋ
a	ā	i	ī	u	ū	ṛ
ॠ	ए	ऐ	ओ	औ	अं	अः
ṝ	e	ai	o	au	aṁ	aḥ

क	ख	ग	घ	ङ
ka	kha	ga	gha	ṅa
च	छ	ज	झ	ञ
ca	cha	ja	jha	ña
ट	ठ	ड	ढ	ण
ṭa	ṭha	ḍa	ḍha	ṇa
त	थ	द	ध	न
ta	tha	da	dha	na
प	फ	ब	भ	म
pa	pha	ba	bha	ma

य	र	ल	व
ya	ra	la	va
श	ष	स	ह
śa	ṣa	sa	ha
ळ	क्ष	त्र	ज्ञ
l̤a	kṣa	tra	jña

ABBREVIATIONS

- PC - PERSEVERATIVE COGNITION
- EEG - ELECTROENCEPHALOGRAM
- PT - PERSEVERATIVE THINKING
- FMI - FREIBURG MINDFULNESS INVENTORY
- PTQ - PERSEVERATIVE THINKING QUESTIONNAIRE
- RRS - RUMINATIVE RESPONSE SCALE
- RAC - RUMINATION ASSESSMENT CHECKLIST
- HR - HEART RATE
- HRV - HEART RATE VARIABILITY
- YP - EARLIER EXPERIENCE OF YOGA
- YPT - AVERAGE HOURS OF PRACTICING YOGA IN A WEEK
- SE - PRESENCE OF STRESSFUL EVENT IN LIFE CURRENTLY
- LSE- LEVEL OF STRESS AT THE MOMENT
- FMI_TOTAL - TOTAL SCORE OF FMI
- REP_SCORE - SCORE FOR REPETITIVENESS IN PTQ
- INT_SCORE - SCORE FOR INTRUSIVENESS IN PTQ
- DISENG_SCORE - SCORE FOR DIFFICULTY TO DISENGAGE IN PTQ
- CF_SCORE- SCORE FOR CORE FEATURES OF REPETITIVE NEGATIVE THOUGHT IN PTQ
- UP_SCORE- SCORE FOR UNPRODUCTIVENESS IN PTQ
- MC_SCORE- SCORE FOR MENTAL CAPACITY IN PTQ
- R_SCORE- REFLECTION SCORE IN RRS
- B_SCORE - BROODING SCORE IN RRS
- RRS_TOTAL - TOTAL SCORE OF RRS
- RAQ_TOTAL - TOTAL SCORE FOR RAQ

ABSTRACT

TITLE: **Characterising and Comparing EEG Signatures of Perseverative cognition For Yoga and Non-yoga Practitioners.**

BACKGROUND: Perseverative cognition has been identified to play an important etiological role in the precipitation of chronic stress into disease. Tools have been created for its subjective identification, only. It is essential to identify the phenomenon objectively. Moreover, it has been shown that the practice of yoga and mindfulness meditation has significant impact on reduction of perseverative cognition. But it is difficult to objectively identify when a practitioner slips into a state of rumination whilst meditating.

AIM: To identify EEG signatures for perseverative cognition and compare those of yoga and non-yoga practitioners.

METHODS**:** Through convenience sampling, 38 students of BSc. Yoga Therapy and MSc. Yoga therapy of Swami Vivekananda Yoga Anusandhana Samsthana university were recruited as yoga practitioners and 23 students of BAMS of Sushruta Ayurveda Medical College & Hospital (SAMC&H) were recruited as non-yoga practitioners. Both groups underwent the same assessments of FMI, PTQ, RRS followed by five and a half minutes each of EEG readings: first, for baseline and second, for rumination, followed by RAC.

RESULTS**:** Alpha frequency was found to be dominant across all group both at rest and during rumination. The Yoga group showed significant correlation for all the main scores except trait and state rumination. There were overall more significant correlations between the main scores within the female group as compared to the male group. Almost all the measures showed a considerable effect size but the overall achieved power of the study is not sufficient, possibly due to the low sample size.

CONCLUSION: Yoga practitioners may have lower perseverative cognition levels compared to non-yoga practitioners.

KEY WORDS: Perseverative cognition, Rumination, Stress, Yoga, EEG, Mindfulness.

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1. INTRODUCTION

A human being tends to go through several thoughts through the day. But no research has been able to definitively put forth an average number for the thoughts that a person has in a day. There is also no denying that the quality and quantity of these thoughts determines our day-to-day functioning not only at a mental but also at a physiological level. It is natural to ruminate about the past and worry about the future, however, these are pervasive and distressing, dysfunctional cognitive processes.

1.1. PERSEVERATIVE COGNITION

In recent years, research has brought to the forefront, the significance of a phenomenon called perseverative cognition in the physiological sustenance of a stress response which leads to various psychosomatic disorders. “The repeated or chronic activation of the cognitive representation of one or more psychological stressors” is termed perseverative cognition (Brosschot, Gerin, & Thayer, 2006). Any event involving potential harm, without or with low perceived control, that is a threat to the psychobiological integrity of oneself or to the attainment of one’s higher order goals can be termed as a stressor. Perseverative cognition is an umbrella term for worry, rumination, all and any cognitive processes, conscious and unconscious, involving stressful events (Brosschot, Verkuil, & Thayer, 2010; Verkuil, Brosschot, Gebhardt, & Thayer, 2010), even daily problems in one’s life, in the past or in the future (Ottaviani, Shapiro, & Couyoumdjian, 2013). The latter is otherwise known as mind wandering, but can be addressed as perseverative cognition when dwelling on negative topics over a period of time.

1.1.1. PHYSIOLOGICAL BASIS OF PERSEVERATIVE COGNITION IN HUMANS

The Hypothalamic - Pituitary - Adrenal (HPA) axis mediates the stress response in the human body with the hypothalamus being a key structure in control of the autonomic nervous system. In healthy people not undergoing stress, the sympathetic and parasympathetic arms of the Autonomic Nervous System are balanced and flexible in terms of response. When one comes in contact with a stimulus, the brain determines whether is a stressor and accordingly a physiological stress response ensues via the autonomic, immune, endocrine, and metabolic systems. Hence the brain plays a pivotal role in the association between cognitive and

autonomic inflexibility.

1.1.2. EVOLUTIONARY BASIS OF STRESS PERCEPTION

Reacting to a stressor when it is present is an adaptive response (Phillips, Ginty, & Hughes, 2013). The period after the stressor is removed from the physical environment of the person is said to be recovery (Panaite, Salomon, Jin, & Rottenberg, 2015). But what is the adaptive response to an ambiguous stressor: When a dog comes across a coiled rope in the dark, it assumes it to be a snake and runs away from the imminent threat. Once it feels it is out of harm's way, all of its physiological biomarkers due to the stressful event - heart rate, blood pressure, breath rate, etc. come back to the normal state. This is considered an adaptive response. But now consider the case when a human being comes across a coiled rope in the dark. While some may be brave enough to go closer to confirm if it is a 'snake', some might freeze right there and some may assume it to be a snake flee from the area. In all three cases, the stress response occurs. But, where it becomes maladaptive is when the person thinks about it later wondering 'What if it were a snake? What if a loved one had been near it? It could've hurt me!' Thus this highlights the person's cognitive inflexibility as it continues to maintain the cognitive representation of the stressor and hence, the stress or so-called fight-flight-freeze response actively over time even after the physical stressor is removed (Verkuil et al., 2010). This inflexibility at a mental level is perseverative cognition and is of evolutionary significance because it is a mental response to a stressor and moreover, it forms an integral missing link to explain stress-related physiological activity prolonging beyond the presence of actual stressors.

1.1.3. IMPACT OF PERSEVERATIVE COGNITION

In one of the foremost reviews on perseverative cognition (Verkuil et al., 2010), it was conclusively presented that prolonged physiological activation is associated with perseverative cognition and somatic health outcomes. In recent times, an exhaustive meta-analysis on the physiological concomitants of perseverative cognition in healthy participants (Ottaviani et al., 2016) propounded that perseverative cognition clearly affects cardiovascular, autonomic, and endocrine nervous system pathways consistent with a pathogenic route to long-term disease outcomes. Specifically, they found significant impact on heart rate, blood pressure, and cortisol activity and heart rate variability during perseverative cognition or related to trait perseverative cognition. Both worry (Brosschot,

Van Dijk, & Thayer, 2007) and rumination (Ottaviani, Shapiro, & Fitzgerald, 2011) have a common autonomic indication - a reduced HRV, which has been associated with physiological problems, such as cardiovascular disease, systemic inflammation, diabetes, high cholesterol, obesity, arthritis, and renal dysfunction (Brotman et al., 2010; Holman et al., 2008; Jarczok, Koenig, & Mauss, 2014; Thayer, Yamamoto, & Brosschot, 2010; Tully, Cosh, & Baune, 2013) in initially healthy people. It is also shown to affect sleep patterns (Weise, Ong, Tesler, Kim, & Roth, 2013).

1.2. YOGA

In the yoga tradition, it is said to be free is to be able to think whatever thoughts you wish to. Perseverative cognition can be viewed as a rigid pattern that involves habitual engagement of circular, looping thoughts, characterized by a failure of effective inhibitory control, with the consequence of perpetuating the physiological threat response.

1.2.1. ROLE OF YOGA IN REGULATING MENTAL & PHYSICAL FUNCTIONS IN HUMANS

Our mental state heavily influences the hypothalamic-pituitary-adrenal (HPA) axis and alters cortisol levels. Cortisol is a hormone discharged from the adrenal cortex. It is a significant biomarker of HPA axis activation and therefore, psychological stress (Yoshihara, Hiramoto, Sudo, & Kubo, 2011). Yoga reduces sympathetic activation, enhances cardiovagal function, and causes a shift in autonomic nervous system from primarily sympathetic to parasympathetic, increased vagal tone, decreased workload on heart, decreased systolic blood pressure (Büssing, Michalsen, Khalsa, Telles, & Sherman, 2012). In the field of cognitive research, it has shown to significantly impact cognitive processes such as attention, concentration, memory (Joice, Manik, & Sudhir, 2018), reaction time (Sonwane & Mishra, 2016) to name a few. With each year, more and more is being learnt about the far-reaching impact of regular yoga practice.

1.2.2. YOGA & EEG CHANGES

Various aspects of yogic practices have been shown to be give various cognitive benefits via their impact on brain wave activity. Various asanas and pranayamas have been shown to lead to increased alpha wave activity & increased theta power (Trakroo, Bhavanani, Pal, Udupa, & Krishnamurthy, 2013). Forced alternate nostril breathing has been shown to increase alpha

wave activity (Stančák & Kuna, 1994). Right nostril breathing has been shown to significantly lower P300 (brain wave related to decision-making process) peak latency in the left brain hemisphere compared to the right. (Telles, Joshi, & Somvanshi, 2012) after practice (Vialatte, Bakardjian, Prasad, & Cichocki, 2009)

1.3. NEED FOR THE STUDY

In the field of yoga, several studies have been done to understand its impact on different cognitive processes, as mentioned above. Various studies have also been done for EEG recordings of subjects in a meditative state, or simply being in a state of observing one's own thoughts. However, it has not been possible to objectively identify when a subject slips into a state of perseverative cognition during this process. Thus, this is the primary purpose of this study, to objectively identify signatures of perseverative cognition.

2 REVIEW OF ANCIENT LITERATURE

2.1 DEFINITION OF MIND

The mind is called in Sanskrit as *manas.* The definition of mind according various Sanskrit texts is presented below.

2.1.1 TARKA SAṄGRAHAḤ

सुखाद्युपलब्धिसाधनमिन्द्रियं मनः।

तच्च प्रत्यात्मनियतत्वादनन्तं परमाणुरूपं नित्यं च॥ २। ९॥

sukhādyupalabdhisādhanamindriyaṁ manaḥ।

tacca pratyātmaniyatatvādanantaṁ paramāṇurūpaṁ nityaṁ ca ।। 2। 9 ।।

Tarka Saṅgrahaḥ, a *Nyāya-Vaiśeṣika* text by *Annambhaṭṭa*, considers the *manas* or mind as one of the *nava-dravyāṇi* or nine substances. The mind is defined as the internal organ which is instrumental in obtaining knowledge of pleasure, pain, etc. According to the *Vaiśeṣika Darśana* of *Kaṇāda,* the mind is infinite, atomic and eternal. It is said to be linked with the human soul.

2.1.2 TATTVABODHAḤ

संकल्प-विकल्पात्मकं मनः निश्चयात्मिका बुद्धिः अहंकर्ता अहंकारः चिन्तनकर्तृ चित्तम्।

saṅkalpa-vikalpātmakaṁ manaḥ niścayātmikā buddhiḥ ahaṅkartā ahaṅkāraḥ cintanakartṛ cittam।

Manas is characterised by indecisiveness. The component of the mind which is responsible for decision making and determination is the *buddhi.* The *ahaṅkāra* gives us the sense of self-consciousness and the *citta* is the mind-floor, which accomodates all the other components.

2.1.3 HAṬHA YOGA PRADĪPIKĀ

ज्ञेयं सर्वं प्रतीतं च ज्ञानं च मन उच्यते ।

ज्ञानं ज्ञेयं समं नष्टं नान्यः पन्था द्वितीयकः ॥ ४ । ६० ॥

jñeyaṁ sarvaṁ pratītaṁ ca jñānaṁ ca mana ucyate ।

jñānaṁ jñeyaṁ samaṁ naṣṭaṁ nānyaḥ panthā dvitīyakaḥ ।। 4 । 60 ।।

मनोदृश्यमिदं सर्वं यत्विकंचित्सचराचरम् ।

मनसो ह्युन्मनीभावाद् द्वैतं नैवोपलभ्यते ॥ ४ । ६१ ॥

manodṛśyamidaṁ sarvaṁ yatvikañcitsacarācaram ।

manaso hyunmanībhāvād dvaitaṁ naivopalabhyate ।। 4 । 61 ।।

The *Haṭha Yoga Pradīpikā* by *Svātmārāma* defines the mind in these two slokas. The knowable, the known and the knowledge together are said to constitute the mind. *Svātmārāma* also says that the entire universe with its sentient and insentient beings is an appearance of the mind. Here we see an Idealistic position taken by the author as he speaks of the mind being the substratum and reality of matter.

2.1.4 SĀṄKHYA KĀRIKĀ

प्रकृतेर्महांस्ततोऽहङ्कारस्तस्माद्गणश्च षोडशकः ।

तस्मादपि षोदशकात्पञ्चभ्यः पञ्च भूतानि ॥ २२ ॥

prakṛtermahāṁstato'haṁkārastasmādgaṇaśca ṣoḍaśakaḥ ।

tasmādapi ṣodaśakātpañcabhyaḥ pañca bhūtāni ।। 22 ।।

The *Sāṁkhya Darśana* speaks of the twenty four evolutes of *Prakṛtī* (nature). This sloka from the *Sāṁkhya Kārikā* of *Īśvarakṛṣṇa* talks about the evolution of the different cosmic principles from *Prakṛtī*. The first evolute of *Prakṛtī* is *mahat* (cosmic intelligence). From *mahat* comes

ahañkāra (cosmic egoism). From *ahañkāra*, the eleven *indriyāṇi* (organs) including *manas* (mind) and the five *tanmātrāḥ* (objects of the five senses) come forth. The eleven *indriyāṇi* are thus: *manas* is the *antaḥkaraṇam* (internal instrument). There are five *jñānendriyāṇi* (organs of knowledge) – *śrotram, tvak, cakṣuḥ, jihvā, nāsikā* and five *karmendriyāṇi* (organs of action) – *vāk, pāṇiḥ, pādaḥ, pāyuḥ, upasthaḥ*. The five *tanmātrāḥ* are *śabda, sparsa, rūpa, rasa* and *gandha*. From these the *pañca mahābhūtāni* (five great elements) proceed respectively – *ākāśaḥ, vāyuḥ, agniḥ, āpaḥ* and *pṛthvī*. These together form the twenty four evolutes of *Prakṛtī*.

2.1.5 YOGA VĀSIṢṬHA

यत् अर्थप्रतिभानं तत् मन इत्यभिधीयते ।

नास्त्यस्य मनसो रूपं संकल्पात् तत् न भिद्यते ॥ ३ । १६ ॥

yat arthapratibhānaṁ tat mana ityabhidhīyate ।

nāstyasya manaso rūpaṁ saṅkalpāt tat na bhidyate ।। 3 । 16 ।।

अविद्या संसृतिः चित्तं बन्धोऽज्ञानं मनः तमः ।

इति संकल्पजालस्य नामान्येतानि राघव ॥ ३ । १७ ॥

avidyā saṁsṛtiḥ cittaṁ bandho'jñānaṁ manaḥ tamaḥ ।

iti saṅkalpajālasya nāmānyetāni rāghava ।। 3 । 17 ।।

The *Yoga Vāsiṣṭha* is a classcial text on *yoga*. These verses speak of the universe that is perceived as made of mind. This mind, which is the substratum of all, is described as being formless. Again we find an example of Idealism in Indian philosophy.

2.2 NATURE OF MIND

The nature of the mind as discussed in different *Yoga* and *Vedānta* texts is presented below.

2.2.1 PĀTAÑJALAYOGASŪTRĀṆI

न तत्स्वाभासं दृश्यत्वात्॥ ४। १९॥

na tatsvābhāsaṁ dṛśyatvāt ।। 4। 19 ।।

This aphorism from the *yoga* aphorisms of *Maharṣi Patañjali* says that the mind is not self-illuminating as it is an object in itself. The mind is an object of our experience, as evident from the fact that we are aware of it. The *Yoga Darśana* states that only the *Puruṣaḥ* – the Self is self illuminating in nature. The mind seems to be sentient, but in reality it only reflects the sentience of the *Puruṣaḥ*.

2.2.2 PĀTAÑJALAYOGASŪTRĀṆI VYĀSA BHĀṢYAM

क्षिप्तं मूढं विक्षिप्तमेकाग्रं निरुद्धमिति चित्तभूमयः॥

kṣiptaṁ mūḍhaṁ vikṣiptamekāgraṁ niruddhamiti cittabhūmayaḥ ।।

Present as a commentary for the first sūtrā of samādhi pāda.

The commentary of *Vyāsa* on the *Yoga* aphorisms of *Maharṣi Patañjali* divide the whole range of mental activities into 5 planes known as the *Citta-bhūmayaḥ*. They are *Kṣipta* (Raving or scattered), *Mūḍha* (Dull or inert), *Vikṣipta* (Oscillating or distracted), *Ekāgra* (One - pointed) and *Niruddha* (Restrained).

2.2.3 BHAGAVADGĪTĀ

चञ्चलं हि मनः कृष्ण प्रमाथि बलवद्दृढम्।

तस्याहं निग्रहं मन्ये वायोरिव सुदुष्करम्॥ ६। ३४॥

cañcalaṁ hi manaḥ kṛṣṇā pramāthi balavaddṛḍham ।

tasyāhaṁ nigrahaṁ manye vāyoriva suduṣkaram ।। 6। 34 ।।

In the *Bhagavad-gītā*, we find *Śrī Kṛṣṇa* extolling the importance of restraining the mind in order to attain peace and happiness. In reply to this, we find *Arjuna* describing the mind as

being as difficult to control as the wind, since it is ever-moving, fickle, unsteady and powerful.

2.2.4 AMṚTABINDŪPANIṢAD

मन एव मनुष्याणां कारणं बन्धमोक्षयोः।

बन्धाय विषयासक्तं मुक्तं निर्विषयं स्मृतम्॥ २॥

mana eva manuṣyāaṇāṁ kāraṇaṁ bandhamokṣayoḥ।

bandhāya viṣayāsaktaṁ muktaṁ nirviṣayaṁ smṛtam ।। 2 ।।

This popular verse from the *Amṛtabindu Upaniṣad* - a minor *Upaniṣad* - says that the mind is cause of both bondage and liberation of man. When the mind is attached to sense objects, it leads to bondage. The mind which is non-attached to objects leads to liberation.

2.2.5 BṚHADĀRAṆYAKA UPANIṢAD

त्रीण्यात्मनेऽकुरुत इति मनो वाचं प्राणम् तान्यात्मनेऽकुरुत अन्यत्रमना अभूवम् नादर्शम्

अन्यत्रामना अभूवम् नाश्रौषम् इति मनसा ह्येव पश्यति मनसा शृणोति। कामः संकल्पो

विचिकित्सा श्रद्धाऽश्रद्धा धृतिरधृतिर्ह्रीर्धीर्भीरित्येतत्सर्व मन एव तस्मादपि पृष्ठत उपस्पृष्टो मनसा

विजानाति॥ १। ५। ३॥

trīṇyātmane'kuruta iti mano vācaṁ prāṇam tānyātmane'kuruta anyatramanā abhūvam nādarśam anyatrāmanā abhūvam nāśrauṣam iti manasā hyeva paśyati manasā śṛṇoti।

kāmaḥ saṅkalpo vicikitsā śraddhā'śraddhā dhṛtiradhṛtirhrīrdhīrbhīrityetatsarva mana eva tasmādapi pṛṣṭhata upaspṛṣṭo manasā vijānāti ।। 1। 5। 3 ।।

This verse from the *Bṛhadāraṇyaka Upaniṣad* sheds light on the role of the mind in the process of acquiring knowledge. Sometimes when we are engaged deeply in some work, we might be oblivious to the sounds in the background. A common sound which we usually ignore is the sound of the fan rotating above our heads. Thus, even though our sense organs

may be functioning properly, we may not acquire knowledge if the mind is not united with the sense organ. Hence this *Upaniṣad* says that it is through the mind that one sees or hears. The verse also mentions ten qualities which belong to the mind – desire, will, doubt, conviction, lack of conviction, steadiness, unsteadiness, shame, intelligence and fear. This is by no means an exhaustive list. The idea is only to say that all these phenomena are in the mental plane.

2.3 RELATION OF MIND WITH TRIGUṆĀḤ

Guṇaḥ is a Sanskrit word which means quality or mode. There are three *guṇāḥ* or qualities - *Rajas* (Mode of passion and dynamism), *Tamas* (Mode of delusion and inertia) and *Sattva* (Mode of knowledge and equilibrium). Everything including the mind is said to be made up of these three qualities. According to *Āyurveda* – the ancient Indian science of life, *Rajas* and *Tamas* are considered to be diseases of the mind, while *Sattva* leads to knowledge and happiness. This section, therefore, deals with the relation between the mind and the three aforementioned qualities.

2.3.1 TATTVABODHAḤ

एतेषां पञ्चतत्त्वानां समष्तिसात्त्विकांशात्

मनोबुद्ध्यहंकार चित्तान्तः करणानि संभूतानि ॥ १८ ॥

eteṣāṁ pañcatattvānāṁ samaṣtisāttvikāṁśāt

manobuddhyahaṅkāra cittāntaḥ karaṇāani sambhūtāni || 18 ||

The *Vedānta Darśana* classifies the whole universe into the *pañca mahābhūtāni* – five great elements. They are *ākāśaḥ* (ether), *vāyuḥ* (air), *agniḥ* (fire), *āpaḥ* (water) and *pṛthvī* (earth). These, again, are constituted of the *triguṇāḥ – Sattva*, *Rajas* and *Tamas*. This verse from the *Tattvabodhaḥ* of *Ādi Śankara* states the mind – *manas*, *buddhi*, *ahaṅkāra* and *citta* - arises out of the totality of *sattva guṇāḥ* of the five great elements.

2.3.2 VEDĀNTA-SĀRAḤ

एते पुनराकाशादिगतसात्त्विकांशेभ्यो मिलितेभ्य उत्पद्यन्ते ॥ ७० ॥

ete punarākāśādigatasāttvikāṁśebhyo militebhya utpadyante ।। 70 ।।

The *Vedānta-Sāraḥ* of *Sadānanda Yogīndra* also speaks of the four components of mind – *manas, buddhi, ahaṅkāra* and *citta* – being made out of the *sattva* parts of the five great elements.

2.3.3 SĀṄKHYA KĀRIKĀ

अध्यवसायो बुद्दिर्धर्मो ज्ञानं विराग ऐश्वर्यम्।

सात्विकमेतद्रुपं तामसमस्माद्विपर्यस्तम्॥ २३॥

adhyavasāyo buddirdharmo jñānaṁ virāga aiśvaryam ।

sātvikametadrupaṁ tāmasamasmādviparyastam ।। 23 ।।

The concept of *guṇāḥ* (modes or qualities) has its origin in the *Sāṅkhya Darśana*. The whole of *Prakṛtī* (nature) is comprised of *triguṇāḥ* (three modes or qualities) – *Rajas* (Mode of passion and dynamism), *Tamas* (Mode of delusion and inertia) and *Sattva* (Mode of knowledge and equilibrium). In this verse from the *Sāṅkhya Kārikā* of *Īśvarakṛṣṇa*, we find that there are four qualities which endow the intellect with *Sattva guṇaḥ* – virtue, wisdom, non-attachment and superhuman power. The intellect is said to be endowed with the mode of *Tamas* when it has the opposite qualities – vice, ignorance, attachment and weakness.

2.3.4 BHAGAVADGĪTĀ

प्रवृत्तिं च निवृत्तिं च कार्याकार्ये भयाभये।

बन्धं मोक्षं च या वेत्ति बुद्धिः सा पार्थ सात्त्विकी॥ १८। ३०॥

pravṛttiṁ ca nivṛttiṁ ca kāryākārye bhayābhaye ।

bandhaṁ mokṣaṁ ca yā vetti buddhiḥ sā pārtha sāttvikī ।। 18 । 30।।

This verse speaks of the intellect which has the quality of *sattva* as possesing the following traits: ability to determine the paths of action and reninciation, what is to be done and what is to be avoided, what is fear and fearlessness and what is bondage and liberation.

यया धर्ममधर्मं च कर्यं चाकार्यमेव च ।

अयथावत्प्रजानाति बुद्धिः सा पार्थ राजसी ॥ १८ । ३१ ॥

yayā dharmamadharmaṁ ca karyaṁ cākāryameva ca ।

ayathāvatprajānāti buddhiḥ sā pārtha rājasī ।। 18 । 31 ।।

The qualities of the intellect endowed with *rajoguṇaḥ* are: inability to perceive the difference between virtue and vice and what is to be done and what is to be avoided.

अधर्मं धर्ममिति या मन्यते तमसावृता ।

सर्वार्थान्विपरीतांश्च बुद्धिः सा पार्थ तामसी ॥ १८ । ३२ ॥

adharmaṁ dharmamiti yā manyate tamasāavṛtā ।

sarvārthānviparītāṁśca buddhiḥ sā pārtha tāmasī ।। 18 । 32 ।।

The qualities of the intellect predominant in *tamoguṇaḥ* are: imagining vice to be virtue and seeing everything upside-down, being wrapped in ignorance.

2.4 DEFINITION OF STRESS

The predominance of *rajoguṇaḥ* and *tamoguṇaḥ* in the mind results in the different imbalances. Stress is one of the most common results of imbalance and is extremely potent in causing diseases of the body. Stress is defined in various Sanskrit texts as follows.

2.4.1 PĀTAÑJALAYOGASŪTRĀṆI

अविद्यास्मितारागद्वेषाभिनिवेशाः क्लेशाः ॥ २ । ३ ॥

avidyāsmitārāgadveṣābhiniveśāḥ kleśāḥ ।। 2 । 3 ।।

अविद्याक्षेत्रमुतरेषां प्रसुप्ततनुविच्छिन्नोदाराणाम्॥ २। ४॥

avidyākṣetramutareṣāṁ prasuptatanuvicchinnodārāṇām ।। *2* । *4* ।।

अनित्याशुचिदुःखानात्मसु नित्यशुचिसुखात्मख्यातिरविद्या॥ २। ५॥

anityāśuciduḥkhānātmasu nityaśucisukhātmakhyātiravidyā ।। *2* । *5* ।।

दृग्दर्शनशक्त्योरेकात्मतेवास्मिता॥ २। ६॥

dṛgdarśanaśaktyorekātmatevāsmitā ।।*2* । *6* ।।

सुखानुशयी रागः॥ २। ७॥

sukhānuśayī rāgaḥ ।।*2* । *7* ।।

दुःखानुशयी द्वेषः॥ २। ८॥

duḥkhānuśayī dveṣaḥ ।। *2* ।*8* ।।

स्वरसवाही विदुषोऽपि तथारुढोऽभिनिवेशः॥ २। ९॥

svarasavāhī viduṣo'pi tathāruḍho'bhiniveśaḥ ।। *2* । *9* ।।

Maharṣi Patañjali in his aphorisms on *yoga* speaks of five causes of distress in the path of *yoga*. The word used by *Patañjali* is '*kleśaḥ*', which has meanings of hindrance, obstracle, distress or poison. *Kleśaḥ* is, therefore, a negative mental attitude which comes in the way of yogic accomplishment. They are – ignorance, egoism, attachment, repulsion and clinging to life. These are the five causes of distress.

Ignorance is considered to be the mother of all distress. It may be dormant, or partly manifest or fully developed. *Patañjali* defines ignorance as taking the non-eternal to be eternal, the impure to be pure, the painful to be pleasurable and the non-self to be the self.

According the *Yoga Darśana*, the real nature of man is pure consciousness, which *yoga* calls the *Puruṣaḥ*. But, out of this ignorance which conceals our real nature from us, we identify ourselves with the body and mind. This wrong identification is the second cause of distress – egoism.

Thinking ourselves to be the body-mind complex, we develop love towards things which make us happy and aversion towards things which make us sad. This attachmemnt and aversion are also considered to be causes of distress.

Finally, we all have a very fundamental clinging on to life. Even the newly born child exhibits this fear of death. This is because the mind carries forward the experience of death from the previous lives. This is the last among the distressors. These are the five causes of distress according to *Patañjali*.

2.4.2 BHAGAVADGĪTĀ

शक्नोतीहैव यः सोढुं प्राक्शरीरविमोक्षणात्।

कामक्रोधोद्भवं वेगं स युक्तः स सुखी नरः॥ ५। २३॥

śaknotīhaiva yaḥ soḍhuṁ prākśarīravimokṣaṇāt ।

kāmakrodhodbhavaṁ vegaṁ sa yuktaḥ sa sukhī naraḥ ।। 5 । 23 ।।

Stress is defined in the *Bhagavad-gītā* as '*kāmakrodhodbhavaṁ vegam*' – the speed of mind borne out of desire and anger. *Śrī Kṛṣṇa* says in this verse that only he who can overcome the urges of anger and desire is a happy man.

अथ केन प्रयुक्तोऽयं पापं चरति पूरुषः।

अनिच्छन्नपि वार्ष्णेय बलादिव नियोजितः॥ ३। ३६॥

atha kena prayukto'yaṁ pāpaṁ carati pūruṣaḥ ।

anicchannapi vārṣṇeya balādiva niyojitaḥ ।। 3 । 36 ।।

श्रीभगवानुवाच

काम एष क्रोध एष रजोगुणसमूद्भवः।

महाशनो महापाप्म विद्ध्येनमिह वैरिणां॥ ३। ३७॥

śrībhagavānuvāca

kāma eṣa krodha eṣa rajoguṇasamūdbhavaḥ ।

mahāśano mahāpāpma viddhyenamiha vairiṇāṁ ।। 3 । 37 ।।

इन्द्रियाणि मनो बुद्धिरस्याधिष्ठानमुच्यते ।

एतैर्विमोहत्येष ज्ञानमावृत्य देहिनम् ॥ ३ । ४० ॥

indriyāṇi mano buddhirasyādhiṣṭhānamucyate ।

etairvimohatyeṣa jñānamāvṛtya dehinam ।। 3। 40 ।।

In these three verses from the 3rd chapter of the *Bhagavad-gītā*, we find *Arjuna* asking *Śrī Kṛṣṇa* about that which forces man to commit sin, even though he might not be willing. The answer given by *Śrī Kṛṣṇa* is that desire and anger borne out of the mode of passion are the great enemies of man which make him commit crimes. These are said to reside in the sense organs, mind and the intellect.

2.5 PERSEVERATIVE THINKING

Perseverative thinking is a phenomenon wherein a person experiences stress even after the initial stressor ceases to exist. This process is brought out beautifully in the *Bhagavad-gītā.*

2.5.1 BHAGAVADGĪTĀ

According to the *Bhagavad-gītā*, when a man thinks of the objects of senses (*viṣayā*), attachment (*saṅga*) towards them arises; from this attachment desire (*kāmaḥ*) is born; from desire anger (*krodha)* arises.

ध्यायतो विषयान्पुंसः सङ्गस्तेषूपजायते ।

सङ्गात्सञ्जायते कामः कामात्क्रोधोऽभिजायते ॥ २ । ६२ ॥

dhyāyato viṣayānpuṁsaḥ saṅgasteṣūpajāyate ।

saṅgātsañjāyate kāmaḥ kāmātkrodho'bhijāyate ।। 2 । 62 ।।

From anger comes delusion (*moha)*; from delusion the loss of memory (*smṛti*); from loss of memory the destruction of discrimination (*buddhi)*; from the destruction of discrimination, he perishes.

क्रोधाद्भवति सम्मोहः सम्मोहात्स्मृतिविभ्रमः ।

स्मृतिभ्रंशाद् बुद्धिनाशो बुद्धिनाशात्प्रणश्यति ॥ २ । ६३ ॥

krodhādbhavati sammohaḥ sammohātsmṛtivibhramaḥ ।

smṛtibhraṁśād buddhināśo buddhināśātpraṇaśyati ।। 2 । 63 ।।

Therefore, from the scriptures we can develop a more comprehensive model as for: a) cause of desire and perseverative thinking, b) adverse effects of uncontrolled perseverative thinking (Rajesh, Ilavarasu, Srinivasan, & Nagendra, 2014).

2.6 CONCEPT OF ADHIJA VYADHI

The psychology of *Yoga* philosophy states that any imbalance at the mental level percolates to the body and reflects as a disease. Thus, acoording to this theory, stress and perseverative thinking have repercussions on the body and result in psychosomatic ailments. This mechanism is explained in the *Yoga Vāsiṣṭha* as follows.

2.6.1 YOGA VĀSIṢṬHA

आधयो व्याधयश्चैवं जायन्ते भूतपञ्चके । कथं श्रुणु विनश्यन्ति राघवानां कुलोद्वह ॥ १० ॥

द्विविधो हि व्याधिरस्तीह सामान्यः सार एव च । व्यवहारश्च सामान्यः सारो जन्मनि यः स्मृतः ॥ ११ ॥

प्राप्तेनाभिमतेनैव नश्यन्ति व्यावहारिकाः । आधिक्षये चाधिभवाः क्षयन्ते व्याधयोऽप्यलम् ॥ १२ ॥

ādhayo vyādhayaścaivaṁ jāyante bhūtapañcake।

kathaṁ śruṇu vinaśyanti rāghavānāṁ kulodvaha।। 10 ।।

dvividho hi vyādhirastīha sāmānyaḥ sāra eva ca।

vyavahāraśca sāmānyaḥ sāro janmani yaḥ smṛtaḥ|| 11 ||

prāptenābhimatenaiva naśyanti vyāvahārikāḥ|

ādhikṣaye cādhibhavāḥ kṣayante vyādhayo'pyalam|| 12 ||

A psychosomatic ailment is one which has its origin in the mind and affects the body. *Yoga Vāsiṣṭha* is a classical *Yoga* text which talks about psychosomatic ailments and their types. It introduces two concepts – *Ādhi* and *Vyādhi. Ādhi* is a disturbance in the mental or subtle level of human existence. When this reflects on the body in the form a disease, it is called *Vyādhi.* The term used in *Yoga Vāsiṣṭha* to describe a psychosomatic ailment is *Ādhija Vyādhi* **–** disease borne out of a mental disturbance. These are classified into two – *Sāmānya* and *Sāra*. *Sāmānya Ādhija Vyādhi* refers to those disorders and diseases which are the result of an unhealthy lifestyle. These can be cured by bringing about a change in the lifestyle and adopting healthy practices. *Sāra Ādhija Vyādhi* refers to those ailments which one is born with. According to the theory of Reincarnation followed by all Indic religions, death is only the destruction of the body. There are layers of human personality which continue to exist post death. These contain impressions of the mental tendencies and find a body which is suitable for the expression of the same. This is why some people are born with birth deformities. Some are born blind, deaf, handicapped other, etc. This is what is called *Sāra Ādhija Vyādhi* and it can only be cured by Self-knowledge. This is the concept of psychosomatic ailments or *Ādhija Vyādhi* mentioned in *Yoga Vāsiṣṭha.*

3. REVIEW OF MODERN LITERATURE

3.1. PERSEVERATIVE COGNITION

The field of stress science has come a long way since the time stress was defined as the nonspecific response of the body to any demand, whether it is caused by, or results in, pleasant or unpleasant conditions (Selye, 1951). By 2003, after numerous studies to understand the etiological role of stress in cardiovascular diseases such as hypertension and coronary heart disease, the reactivity hypothesis gained acceptance as the theoretical explanation to understand the link between stress and disease. Frequent high physiological response was said to possibly lead to tissue damage, loss of homeostasis, and over time, disease (Gerin et al., 2000).

This study, however, proposed that it could be due to both positive and negative affect. Therefore, the hypothesis that negative emotions induced a prolonged response compared to positive emotions (Brosschot & Thayer, 2003) was tested. The study used cardiovascular activation to measure the response. The results reinforced that prolonged activation, not reactivity, could be a possible mechanism that causes negative emotions such as stress to precipitate into a somatic disease. And the cause for this prolonged activation could be perseverative cognition.

Following this, the stress theory was expanded stating that prolonged activation is not simply caused to perceiving stress and responding to it (Brosschot, Pieper, & Thayer, 2005). It is essential that the cognitive representation of the stressor is actively prolonged to result in a prolonged physiological activation. Here, they postulated that perseverative cognition, in the form of worry, rumination and anticipatory stress may be the psychological mediator for prolonged activation.

Prolonged activation can be described as being of three types (a) slow recovery after acute prolonged stressor-related activation, (b) recurring prolonged activity after initial recovery, and (c) prolonged activity in anticipation of a stressor (Pieper & Brosschot, 2005).

Thus after reviewing evidences for worry, rumination, anticipatory stress and their association with enhanced cardiovascular, endocrinological, immunological and neurovisceral activity, it was hypothesised that perseverative cognition was the core

cognitive phenomenon which played a significant role in the manifestation of psychosomatic diseases (Brosschot et al., 2006).

In tandem with this hypothesis, it was shown that in addition to impact of stressful events, worrying on a daily basis, especially in the form of work-related and anticipatory stress, may have substantial impact on cardiac activity, such as slow cardiovascular recovery which can lead to adverse cardiovascular outcomes (Pieper, Brosschot, van der Leeden, & Thayer, 2007).

In 2009, the impact of two types of trait perseverative cognition on cardiac recovery after a stressful event was studied (Verkuil, Brosschot, de Beurs, & Thayer, 2009). They also investigated if the two types of state PC: explicit (negative intrusive thoughts) or implicit (automatic vigilance) caused slower cardiac recovery. The results provided evidence that trait & state PC, both, caused delayed cardiac recovery. Brooding, a trait rumination aspect, undermines the HRV suppressing effect of high trait worry. Heart Rate was also found to increase during rumination episodes compared to non-ruminative periods (Ottaviani et al., 2011).

Moreover, PC has also been established as a mediator linking day-level stress to objective & subjective sleep parameters (Van Laethem, Beckers, van Hooff, Dijksterhuis, & Geurts, 2016). Trait worrying has also been shown to be associated with subjective sleep difficulties. Worrying before sleep impairs the sleep process according to both subjective and objective sleep parameters, including heightened sympathetic and reduced parasympathetic activation (Weise et al., 2013)

AUTHOR/ YEAR	SAMPLE / GROUPS	INTERVENTION	ASSESSMENT	RESULTS / CONCLUSION
(Brosschot & Thayer, 2003)	12 males, 21 females, M=29.18	Over an 8 hour period, subjects reported their emotional arousal, emotional valence and physical activity and recorded their heart rate - 1 initial reading after each 60th min	HR, Emotional arousal, Emotional valence, Physical activity	PA, triggered by PT could be etiologically linked to stress to precipitate into a somatic disease.
(Pieper et al., 2007)	49 males, 24 females teachers, M=46.7, SD=9.5	Computerized diaries recorded number & characteristics of worry episodes & stressful events on hourly basis from 8 AM to 10 PM daily for 4 days	Number & characteristics of worry episodes & stressful events, HR, HRV	Compared with neutral periods, worry episodes and stressful events had independent effects on HR and HRV.
(Verkuil et al., 2009)	12 males, 47 females M=22.4, SD=3.66	HR and HRV continuously measured in a non-invasive manner along with administration of PSWQ, RRS, manipulated IQ task, lexical decision task, Sarason Cognitive Interference Scale	HR, HRV, state PC, trait PC, cognitive stress task, implicit PC, explicit PC, state anxiety, state sadness, CS, CC & AB consumed since waking on the day of participation, height, weight, use of medication, presence of chronic disease	Trait & state PC, both, caused delayed cardiac recovery. Brooding, a trait rumination aspect, undermines the HRV suppressing effect of high trait worry.

(Ottaviani et al., 2011)	27 males (M=31.8 SD=10.1), 33 females (M=34.7, SD=8.6)	HR, SBP, DBP were monitored during baseline, reading, an anger recall interview, and recovery. Half of the sample was assigned to a distraction condition. The lab session was followed by a 24-hour ambulatory (A) HR and BP recording and self-reports of moods and rumination.	HR, SBP, DBP, AHR, affect ratings, state and trait rumination, presence & duration of rumination, stressors, or both during the preceding entry period, information on factors that may affect BP, including posture, physical activity, and food, caffeine, nicotine, and alcohol consumption since the last diary report.	Rumination was associated with higher SBP, DBP, and HR and increased negative mood compared to distraction. Rumination during the day was a strong predictor of AHR, ABP, and mood. BP reactivity in the laboratory and increases in ABP during rumination were related. The effects of negative cognition on health go far beyond the recovery periods usually measured in the laboratory, thus playing a pathogenic role.
(Van Laethem et al., 2016)	35 females, 9 males (M=35, SD=10.1)	Subjects were followed from 1 month before their public thesis defence (i.e. stressful life event), until 1 month thereafter. They completed short evening & morning questionnaires on 8 occasions	Day-level stress, sleep quality, PC, objective sleep parameters	Day-level stress was significantly associated with day-level PC. Daily variations in PC were significantly related to

		(in anticipation of & following the defence).		several day-level objective & day-level subjective sleep parameters. On the day level, PC functions as a mediator between stress and sleep parameters - subjective sleep quality, objective sleep efficiency, and subjective wake after sleep onset.
(Weise et al., 2013)	39 high worriers, 16 low worriers	In a 24-h ambulatory monitoring, subjects maintained a log of worry and sleep characteristics while actigraphy, HR, SC, and ambient temperature were recorded.	Actigraphy, HR, SC, sleep quality, state worry, trait worry, sleep onset and offset	While trait worry is mainly associated with subjective sleep difficulties, worrying in bed impairs sleep according to both subjective and objective sleep parameters, including heightened sympathetic and reduced parasympathetic activation.

ABBREVIATIONS: *M - Mean age in years; SD - Standard deviation of age in years; PA - Prolonged activation; HR - Heart Rate; HRV - Heart rate variability; PSWQ - Penn State Worry Questionnaire; CC - number of cups of coffee; AB - number of alcoholic beverages; CS - number of cigarettes smoked; SBP - Systolic Blood Pressure; DBP - Diastolic Blood Pressure, SC - Skin Conductance*

3.2. EFFECT OF YOGA ON REDUCTION OF PERSEVERATIVE COGNITION

Yoga has been shown to have significant effects on reducing tendencies towards perseverative cognition. Practice of Yoga-nidra may decrease perceived stress, worry, and depression and increase mindfulness (Eastman-Mueller, Wilson, Jung, Kimura, & Tarrant, 2013; Hylander, Johansson, Daukantaitė, & Ruggeri, 2017). Mindfulness meditation also reduces distress via decreased rumination (Jain et al., 2007). Lower levels of somatic stress, worry, and negative emotion can be observed after a suryanamaskar intervention for college students (Godse, Shejwal, & Godse, 2015). Mindfulness meditation has been shown to decrease help in lifetime affective disorders by progressively decreasing rumination with increased practice (Wolkin, 2015).

AUTHOR / YEAR	SAMPLE / GROUPS	INTERVENTION	ASSESSMENT	RESULTS / CONCLUSION
(Eastman-Mueller et al., 2013)	66 subjects (aged 18-56 years)	8-week yoga-nidra intervention was offered for 8 semesters. Assessment occurred 1 week prior to intervention onset and during the class period following the intervention. Qualitative data were collected at Weeks 4 and 8.	Perceived stress, worry, depression, mindfulness based skills	Post intervention, statistically significant improvements in perceived stress, worry, and depression were found. Improvements in mindfulness-based skills were also detected. Yoga-nidra practice may reduce symptoms of perceived stress, worry, and depression and increase mindfulness-based skills.
(Hylander et al., 2017)	*Group 1* (22 females, 2 males, M=28, SD=11), *Group 2* (23 females, 2 males, M=31, SD=11)	Group 1 participated in a 5 week yin yoga intervention twice/week. Group 2 was assigned to a waiting-list condition. All measures were administered through self-report questionnaires (PSS, PSWQ, FFMQ)	Perceived stress, worry, mindfulness	Yoga significantly decrease stress & worry, and increases mindfulness.

(Jain et al., 2007)	15 males, 66 females (M=25) 3 groups: *MM* (N=27); *SR* (N=24); *Waitlist Control* (N=30)	MM intervention - body scan, hatha yoga, walking meditation, loving-kindness meditation. SR intervention - body awareness based relaxation. Both interventions given for respective group for 1.5 hr session/week for 4 weeks. Both groups also participated in a 6 hr retreat between session 3 and 4. Self-report questionnaires given 10 days pre-intervention and within 2 weeks after completion of intervention	Psychological symptoms of distress, positive psychological states, amount and types of stress reduction activities engaged in during the week, amount of time experimental subjects spent practicing respective technique, ruminative thoughts and behaviors, spirituality, socially desirable responding	Both meditation and relaxation groups experienced significant decreases in distress as well as increases in positive mood states over time, compared with the control group. Effect sizes for distress were large for both meditation and relaxation. Meditation group showed a larger effect size for positive states of mind than relaxation. The meditation group also demonstrated significant pre post decreases in both distractive and ruminative thoughts/behaviors compared with the control group. mediation models suggesting that mindfulness meditation's effects on reducing distress were partially mediated by reducing rumination.

(Godse et al., 2015)	80 subjects (ages 17-22 years) randomly allocated equally to *experimental & control groups*	Experimental group received 20 mins of Surya namaskar each day for 14 days. Control group was monitored to ensure that they didn't engage themselves in any other relaxation activities.	Somatic stress, worry, negative emotion, relaxation dispositions	Suryanamaskar is effective in leading to Relaxation Dispositions like physical relaxation, mental quiet, at ease/peace, rested and refreshed, strength and awareness and joy and reduces sleepiness, somatic stress, worry and negative emotion at a dispositional level.

ABBREVIATIONS: *M - Mean age in years; SD - Standard deviation of age in years; PSS - Perceived Stress Scale; PSWQ - Penn State Worry Questionnaire; FFMQ- Five Facet Mindfulness Questionnaire, N - Number of subjects in group; MM - Mindfulness Meditation; SR - Somatic Relaxation*

3.3. USE OF EEG FOR IDENTIFYING STRESS

It is known that gamma-band (approximately 30-100 Hz) is suitable for emotion recognition (Li & Lu, 2009). But for the purpose of this study, the focus was to identifying perseverative cognition and its facets of worrying and rumination. It is known that frontal asymmetry is a good measure for emotion and motivation. Higher engagement of the left frontal brain compared to the right frontal brain is associated with positive feelings and higher engagement (Coan & Allen, 2003).

The EEG correlates of mental stress are unique superimposed patterns of various cognitive domains. (Singh & Sharma, 2015). Theta/beta ratio has been known to link effects of stress on state attentional control and can be a useful biomarker for anxiety–cognition interactions (Putman, Verkuil, Arias-Garcia, Pantazi, & van Schie, 2014). Furthermore, prefrontal Relative Gamma has been shown to be more discriminatory with regards to stress levels than alpha asymmetry, theta, alpha, beta, and gamma power in prefrontal cortex (Minguillon, Lopez-Gordo, & Pelayo, 2016).

AUTHOR / YEAR	SAMPLE / GROUPS	INTERVENTION	ASSESSMENT	RESULTS / CONCLUSION
(Li & Lu, 2009)	8 males, 2 females; M=25; all normal sight and right handed	The stimuli consisted of 2 kinds of emotional facial expression pictures—smile and cry. Subjects were asked to focus their attention only on the facial expressions. Additionally, they were also required to keep their head and body steady during the presentation of the pictures while EEG data was recorded from 62 channels.	EEG	Gamma-band (approximately 30-100 Hz) is suitable for emotion recognition
(Coan & Allen, 2003)	32 subjects aged 17-24 years; all strongly right-handed	Resting EEG was recorded from face and scalp while participants sat quietly in a sound-attenuated room for an 8-min resting period, consisting of a counterbalanced sequence of minute-long eyes-open and eyes-closed segments	EEG, BAS, BIS	Higher engagement of the left frontal brain compared to the right frontal brain is associated with positive feelings and higher engagement.
(Singh & Sharma, 2015)	34 subjects	Psychological stress was induced by asking the participants to play a pre-decided stressful computer game while recording HR & GSR. EEG was recorded from 19 scalp locations.	GSR, HR, EEG	The EEG correlates of mental stress are unique superimposed patterns of various cognitive domains.
(Putman et al., 2014)	80 subjects randomly allocated	EEG was measured at the beginning. Visual analog scales for state anxiety and state attentional control were done before and after procedure for	EEG, State anxiety,	Theta/beta ratio has can be a useful electrophysiological biomarker for anxiety–cognition interactions

	equally to a *stress and control group*.	both groups. Participants completed t-STAI, ACS a day after procedure. Stress group underwent a scripted bogus mental arithmetic test with a stern examiner and a recording camera while control group underwent a computerized mental arithmetic task without feedback or cameras. EEG was recorded for 8 min continuously in alternating 1-min blocks of eyes open/eyes closed recording.	Trait anxiety, Trait attentional inhibition	
(Minguillon et al., 2016)	6 healthy subjects	Montreal Imaging Stress Task followed by stay within a relaxation room	EEG, ECG	Prefrontal Relative Gamma (RG) power correlated with expected stress level and heart rate. The difference in prefrontal RG between time periods of different stress level was statistically significant. RG was more discriminative between stress levels than alpha asymmetry, theta, alpha, beta, and gamma power in prefrontal cortex.

ABBREVIATIONS: *M - Mean age in years; SD - Standard deviation of age in years; BIS - Behavioral Inhibition System; BAS - Behavioral Activation System; GSR - Galvanic Skin Response; HR - Heart Rate; STAI-t -trait version of State–Trait Anxiety Inventory; ACS - Attentional Control Scale; ECG - Electrocardiogram*

4. AIMS & OBJECTIVES

4.1. AIMS

To characterise & compare the EEG signatures for perseverative cognition between yoga and non-yoga practitioners.

4.2. OBJECTIVES

- To assess the EEG signatures and subjectively reported perseverative cognition levels.
- To compare EEG signatures for Perseverative cognition between yoga and non-yoga practitioners.

4.3. HYPOTHESIS

The EEG spectral signatures are different for yoga and non-yoga practitioners.

4.4. NULL HYPOTHESIS

There is no difference in EEG spectral signatures for yoga and non-yoga practitioners.

5. METHODS

5.1. SOURCE OF SUBJECTS

38 subjects (18 women, 20 men, *M*=25.02 yrs, *SD*=5.65) were sourced from students of MSc. Yoga Therapy and BSc. Yoga Therapy courses of SVYASA University as yoga practitioners. These included participants who had daily exposure to some form of yoga or mindfulness practice for the at least the past one year. 23 subjects (12 women, 11 men, *M*=23.96 yrs, *SD*=5.05) were sourced from students of BAMS course of Sushruta Ayurveda Medical College as non-yoga practitioners. These subjects reported that they had no exposure to yoga or any mindfulness practices on a daily basis for the past one year. The subjects were provided no compensation for participating in the study.

5.1.1. INCLUSION CRITERIA

Any healthy individual, either male and female, between the age 18-45 years, willing to participate in the study, fluent in reading and writing English language, having basic knowledge of computers could be included as a subject in the study. It was also ensured that the readings for female subjects were taken at least 2 days before/after menses.

5.1.2. EXCLUSION CRITERIA

Any individual with a known pathology of a clinically diagnosed psychiatric illness, clinical history of epilepsy, parkinsonism, Alzheimer's, sleep disorders and diagnosed organic pathology of the brain was excluded from the study.

5.2. ETHICAL CONSIDERATION

All participants were informed about the experiment beforehand and informed consent was obtained digitally. The investigators did not use participants' information except for the aim of this research. At any given point during the research process, the participant had complete freedom to withdraw from the experiment without any liability.

5.3. DESIGN OF THE STUDY

This study has a cross sectional design. There are two groups, yoga and non-yoga practitioners. In certain instances, non-yoga practitioners are also referred to as control group.

5.4. ASSESSMENT TOOLS

5.4.1. ELECTROENCEPHALOGRAM BY OPENBCI

openBCI, a low-cost portable Brain-Computer Interface, was used to collect data for this study. We used the system incorporated with the 3D printed and assembled *Ultracortex 'Mark IV'* EEG headset, a *Cyton* board and a *Daisy* module, which together provide data through 16 channels. The *Cyton* Board communicates with the computer via the *openBCI* Dongle through *bluetooth*. The electrodes used are dry electrodes. The electrode placement follows the international 10/20 system. Measurements were taken through all 16 channels. Data was recorded and stored on the computer through the *openBCI GUI* software.

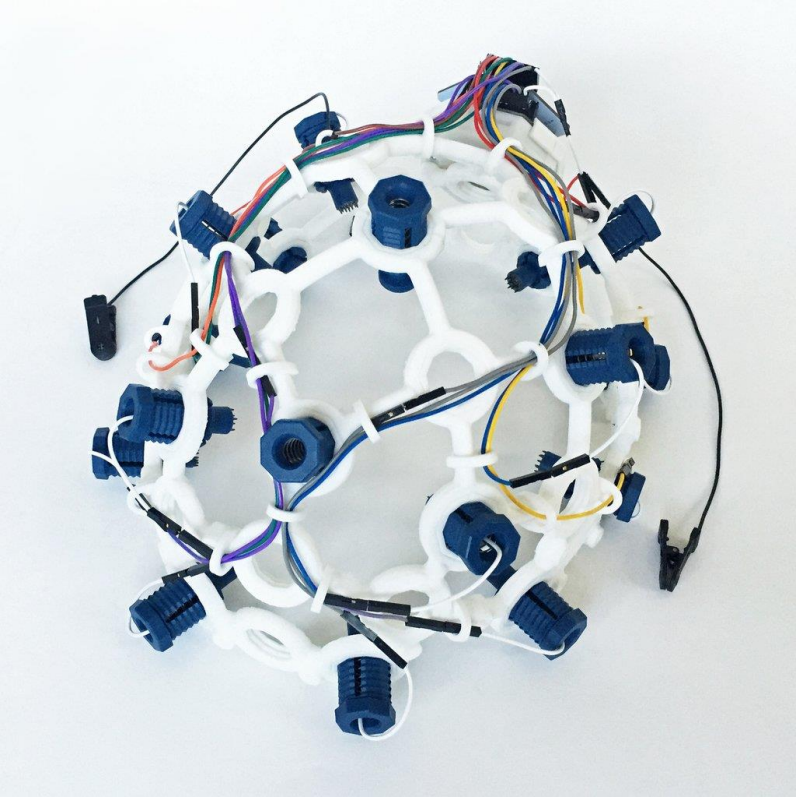


Figure 1. Ultracortex Mark IV headset by openBCI

5.4.2. FREIBURG MINDFULNESS INVENTORY

The FMI (Walach, Buchheld, Buttenmüller, Kleinknecht, & Schmidt, 2006) is a self-reported 14-item, Likert-type scale designed to measure mindfulness in contexts where the subjects are

not familiar with the concept of mindfulness. The questionnaire aims to characterise the subject's mindfulness. Items are rated on a four-point scale: 1 - Rarely, 2 - Occasionally, 3 - Fairly Often, 4 - Almost Always.

5.4.3. PERSEVERATIVE THINKING QUESTIONNAIRE

The PTQ (Ehring et al., 2011) is a self-reported, 15-item, Likert-type scale designed to measure the broad idea of repetitive negative thought. The items on the scale assess what are considered to be the core aspects of repetitive negative thought: 1) their repetitive and intrusive nature, 2) the perceived unproductive nature of these thoughts, and 3) the way in which this type of thinking captures mental capacity. In this study, the scale was used to measure trait rumination. Items are rated on a five-point scale: 0 - Never, 1 - Rarely, 2 - Sometimes, 3 - Often, 4 - Almost Always.

5.4.4. RUMINATIVE RESPONSE SCALE

Rumination is a type of perseverative cognition that focuses on negative subjects, mainly past and present, and lead to emotional distress. (Sansone & Sansone, 2012). The RRS (Treynor, Gonzalez, & Nolen-Hoeksema, 2003) is a self-reported, 22-item, Likert-type scale describing responses to depressed mood that are focused on symptoms and the possible causes and consequences of distressed mood. In this study, the scale was used to measure state rumination. Items are rated on a four-point scale: 1 - Almost never, 2 - Sometimes, 3 - Often, 4 - Almost always.

5.4.5. RUMINATION ASSESSMENT CHECKLIST

The RAC was developed with the aim to assess the extent to each subject was able to ruminate during the rumination reading. It is a self-reported, 5-item, Likert-type scale measuring state rumination. The first item is rated on a seven-point scale - 1 being 'Positive' to 4 being 'Neutral' to 7 being 'Negative'. The remaining four items are rated on a seven-point scale - 1 being 'Not at all', to 7 being 'Very much'.

5.5. INTERVENTION

The experimental protocol and algorithm for analysis of the EEG data was created in collaboration with students from MS Ramaiah Institute of Technology, Bengaluru.

Each subject was given a specific set of instructions to follow in the 24 hour period before the reading.

1. Ensure that hair is washed properly on the day of the reading.
2. Ensure sufficient sleep the night before the reading.
3. Avoid applying oil to hair or creams to forehead region.
4. Avoid coffee/tea/alcohol consumption.
5. Avoid excess physical activity.

The flowchart on the next page explains the experimental protocol. All data was collected digitally.

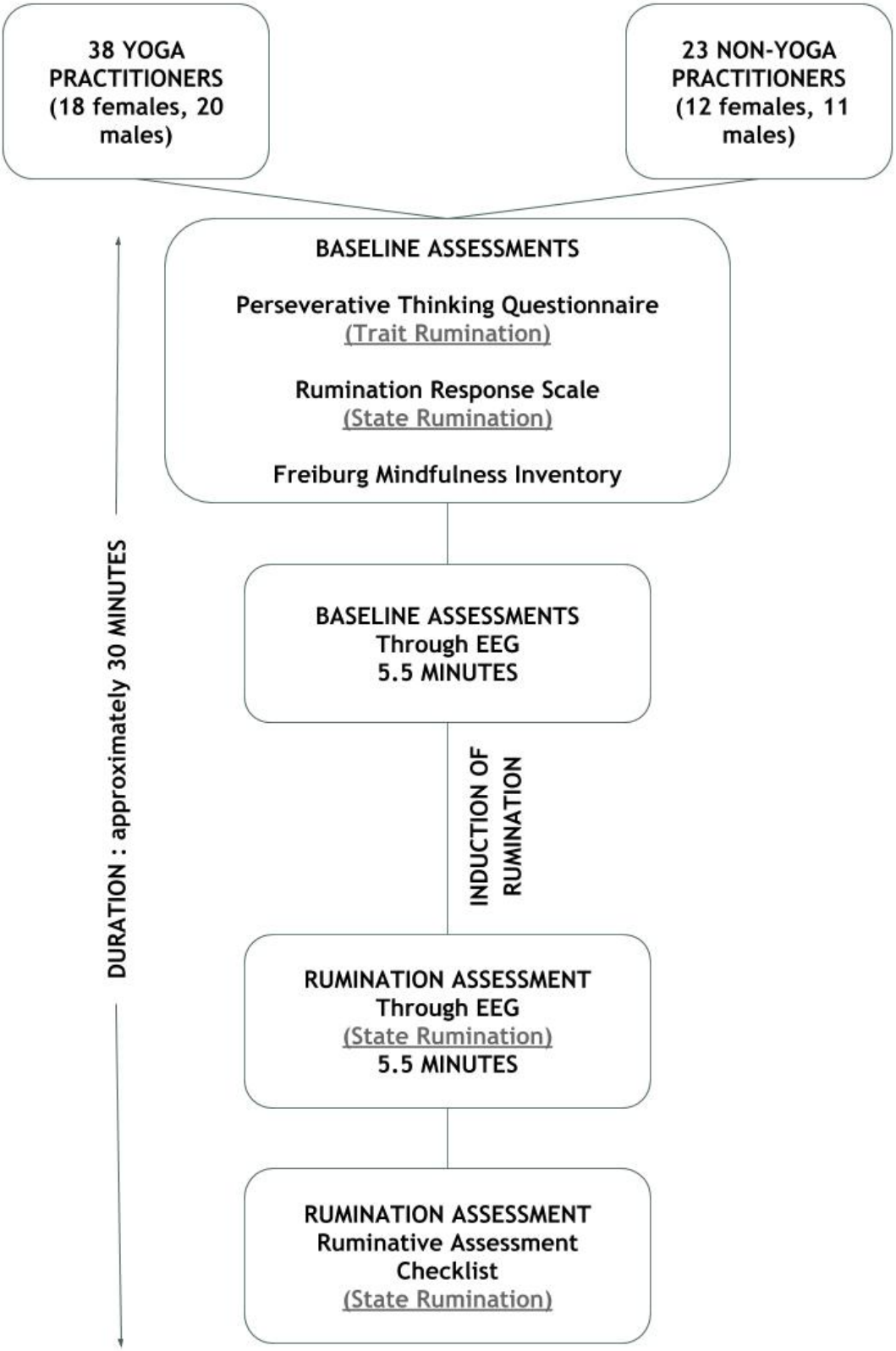


Figure 2. Flowchart depicting design of the study

5.6. DATA EXTRACTION & ANALYSIS

5.6.1. QUESTIONNAIRES

All the questionnaires were administered through Inquisit 4. Results were then exported to Microsoft Excel 2013 and consolidated into a master sheet including total scores and subscale scores for each questionnaire with reverse scoring. Further analysis was done on R studio. It included checking reliability of all 4 questionnaires. Analysis was done group wise and gender wise - demographics, descriptive statistics, outliers, correlation between the scores in each group & independent sample t-tests for each score between two groups.

5.6.2. EEG DATA

Using the openBCI GUI, two files were generated for each subject - one for the baseline reading and one for the rumination reading.

5.6.2.1. EEGrunt

Each output data file was individually then run through EEGrunt, a group of open-source Python utilities for EEG analysis + display for openBCI. It loads data from OpenBCI, filters, and generates plots and spectrograms.

For the analysis of this study, we used Spyder 3.3 (Scientific Python Development EnviRonment) to:

- Edit the code for some optional settings variables:
    - Number of channels - 16
    - Sampling rate - 125 Hz
    - Band pass filter - 3-42 Hz
- Filter out 50Hz mains interference (notch filter) and run a 1 Hz high pass filter to remove DC components of the signal.
- Create a power spectrum plot (average power at each frequency) for each channel in each file and store it for future usage.

6. RESULTS

6.1. QUESTIONNAIRES

6.1.1. GROUP WISE DEMOGRAPHICS

	YOGA PRACTITIONERS	NON-YOGA PRACTITIONERS
N (%)	38 (63.3)	23 (37.7)
MALES (%)	20 (52.63)	11 (47.83)
FEMALES (%)	18 (47.37)	12 (52.17)
MEAN AGE (SD)	25.03 (5.65)	23.96 (5.05)
AVERAGE HOURS OF YOGA PRACTICE PER WEEK	7	0.22
% OF SUBJECTS WITH STRESSFUL EVENT IN LIFE	34.21	65.22
AVERAGE LEVEL OF STRESS ON A SCALE OF 1-7	2.82	3.52

TABLE 1: GROUP WISE DEMOGRAPHICS

6.1.2. DESCRIPTIVE STATISTICS OF MAIN SCORES

YOGA PRACTITIONERS (n=38)

	mean	sd	median	min	max
fmi_total	41.55	5.09	43.0	29	50
rep_score	5.87	2.32	5.0	2	12
int_score	6.13	2.20	6.0	3	12
diseng_score	5.00	2.49	4.5	2	11
CF_score	17.00	6.49	15.5	7	35
UP_score	4.76	2.48	5.0	1	11
MC_score	5.16	2.32	5.0	1	10
ptq_total	26.92	10.38	23.5	9	55
r_score	11.47	3.06	11.0	5	18
b_score	10.55	3.06	10.5	6	18
rrs_total	46.13	11.09	44.0	25	78
raq_total	17.76	4.61	17.0	8	28

TABLE 2: ABBREVIATIONS: ***fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist*

NON-YOGA PRACTITIONERS (n=23)

	mean	sd	median	min	max
fmi_total	39.30	8.17	42	21	50
rep_score	6.35	2.85	7	2	12
int_score	6.43	2.25	6	3	12
diseng_score	5.35	3.11	5	1	12
CF_score	18.13	7.44	16	7	34
UP_score	5.00	2.78	5	0	10
MC_score	5.22	3.06	5	0	12
ptq_total	28.35	11.88	27	8	56
r_score	9.96	2.95	9	6	16
b_score	10.78	3.34	10	5	18
rrs_total	46.22	12.76	45	25	75
raq_total	19.91	5.90	18	11	35

TABLE 3: ABBREVIATIONS: ***fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist*

MALE GENDER (n=31)

	mean	sd	median	min	max
fmi_total	42.55	5.30	43	27	50
rep_score	5.39	2.08	5	2	11
int_score	5.84	1.88	6	3	10
diseng_score	4.81	2.52	4	1	12
CF_score	16.03	5.95	14	7	33
UP_score	4.81	2.57	5	0	10
MC_score	4.84	2.53	5	1	10
ptq_total	25.68	9.83	23	9	50
r_score	10.65	2.81	11	5	16
b_score	10.06	2.93	9	6	16
rrs_total	44.87	10.00	43	25	62
raq_total	17.45	4.54	17	8	27

TABLE 4: ABBREVIATIONS: ***fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist*

FEMALE GENDER (n=30)

	mean	sd	median	min	max
fmi_total	38.80	7.05	41.5	21	48
rep_score	6.73	2.78	6.5	2	12
int_score	6.67	2.45	7.0	3	12
diseng_score	5.47	2.92	5.0	1	12
CF_score	18.87	7.45	18.0	7	35
UP_score	4.90	2.62	5.0	1	11
MC_score	5.53	2.66	5.5	0	12
ptq_total	29.30	11.78	27.0	8	56
r_score	11.17	3.37	11.0	6	18
b_score	11.23	3.30	11.0	5	18
rrs_total	47.50	13.16	46.0	25	78
raq_total	19.73	5.63	18.0	12	35

TABLE 5: ABBREVIATIONS: ***fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist*

6.1.3. RELIABILITY OF QUESTIONNAIRES

QUESTIONNAIRE	NUMBER OF ITEMS	RELIABILITY
Freiburg Mindfulness Inventory	14	0.79
Perseverative Thinking Questionnaire	15	0.93
Ruminative Response Scale	22	0.92
Rumination Assessment Checklist	5	0.77

TABLE 6: RELIABILITY OF QUESTIONNAIRES

6.1.4. CORRELATION OF MAIN SCORES GROUP WISE

YOGA PRACTITIONERS (n=38)

	1	2	3	4	5	6	7	8	9	10	11
1. fmi_total											
2. rep_score	-.40*										
3. int_score	-.33*	.82**									
4. diseng_score	-.46**	.83**	.72**								
5. CF_score	-.43**	.95**	.90**	.92**							
6. UP_score	-.42**	.71**	.49**	.70**	.69**						
7. MC_score	-.43**	.78**	.66**	.78**	.80**	.69**					
8. ptq_total	-.47**	.94**	.83**	.92**	.97**	.82**	.89**				
9. r_score	-0.06	.47**	.43**	.34*	.44**	0.17	.39*	.41*			
10. b_score	-.34*	.60**	.33*	.42**	.49**	.51**	.44**	.52**	.48**		
11. rrs_total	-0.19	.63**	.48**	.52**	.59**	.43**	.52**	.59**	.82**	.82**	
12. raq_total	-.33*	.57**	.33*	.53**	.52**	.44**	.45**	.53**	-0.01	.38*	0.27

TABLE 7: *p-value<0.05 - *; p-value<0.01 - **; p-value<0.001 - ***;* **ABBREVIATIONS:** ***fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist*

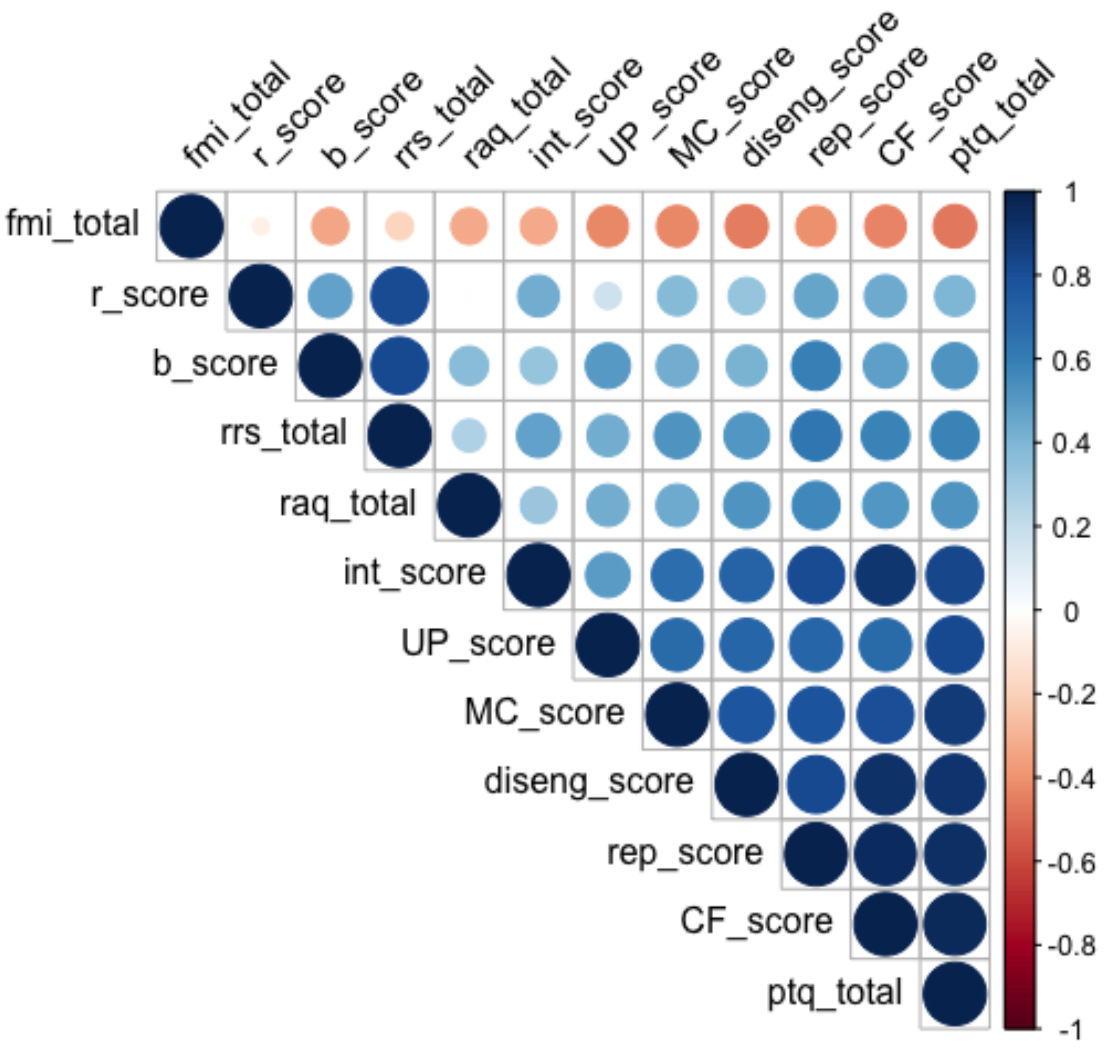


Figure 3. Graphical representation of correlation of main scores in Yoga Practitioners with significance levels

[*p-value<0.05 - *; p-value<0.01 - **; p-value<0.001 - ***;* **ABBREVIATIONS:** ***fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist*]

NON-YOGA PRACTITIONERS (n=23)

	1	2	3	4	5	6	7	8	9	10	11
1. fmi_total											
2. rep_score	-0.41										
3. int_score	-0.18	.63**									
4. diseng_score	-0.27	.81**	.70**								
5. CF_score	-0.33	.91**	.84**	.94**							
6. UP_score	-.66**	.52*	0.23	.63**	.53**						
7. MC_score	-.42*	.82**	.59**	.77**	.82**	.56**					
8. ptq_total	-.47*	.91**	.73**	.94**	.96**	.71**	.90**				
9. r_score	-0.23	.60**	.62**	.64**	.68**	0.27	.65**	.66**			
10. b_score	-.42*	.49*	.53**	.64**	.62**	.58**	.62**	.68**	.45*		
11. rrs_total	-.50*	.67**	.64**	.69**	.74**	.51*	.71**	.77**	.79**	.81**	
12. raq_total	-0.39	.71**	0.32	.66**	.65**	.62**	.57**	.69**	.64**	.43*	.61**

TABLE 8: *p-value<0.05 - *; p-value<0.01 - **; p-value<0.001 - ***;* **ABBREVIATIONS:** ***fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist*

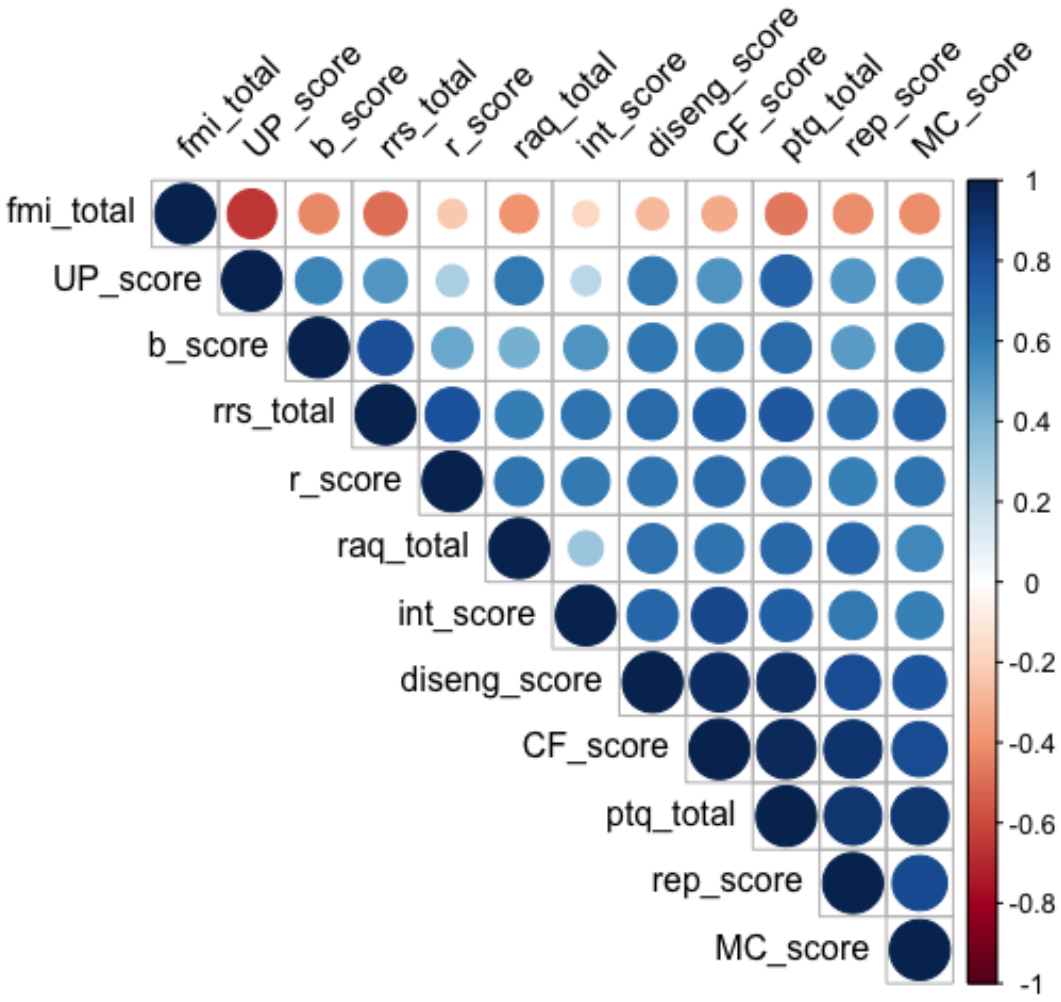


Figure 4. Graphical representation of correlation of main scores in Non-Yoga Practitioners with significance levels

[*p-value<0.05 - *; p-value<0.01 - **; p-value<0.001 - ***;* **ABBREVIATIONS:** ***fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist*]

MALE GENDER (n=31)

	1	2	3	4	5	6	7	8	9	10	11
1. fmi_total											
2. rep_score	-0.28										
3. int_score	0	.68**									
4. diseng_score	-0.29	.89**	.68**								
5. CF_score	-0.22	.94**	.84**	.95**							
6. UP_score	-.44*	.66**	0.3	.66**	.61**						
7. MC_score	-0.34	.74**	.50**	.71**	.72**	.61**					
8. ptq_total	-0.33	.94**	.72**	.93**	.95**	.79**	.85**				
9. r_score	-0.13	.38*	0.29	0.3	0.35	0.22	.37*	.36*			
10. b_score	-0.04	.42*	0.03	0.31	0.29	.43*	0.33	.37*	.38*		
11. rrs_total	-0.18	.46**	0.16	0.35	.36*	.45*	.41*	.44*	.80**	.78**	
12. raq_total	-.47**	.61**	0.28	.62**	.57**	.68**	.49**	.65**	0.04	.42*	.36*

TABLE 9: *p-value<0.05 - *; p-value<0.01 - **; p-value<0.001 - ***;* **ABBREVIATIONS:** ***fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist*

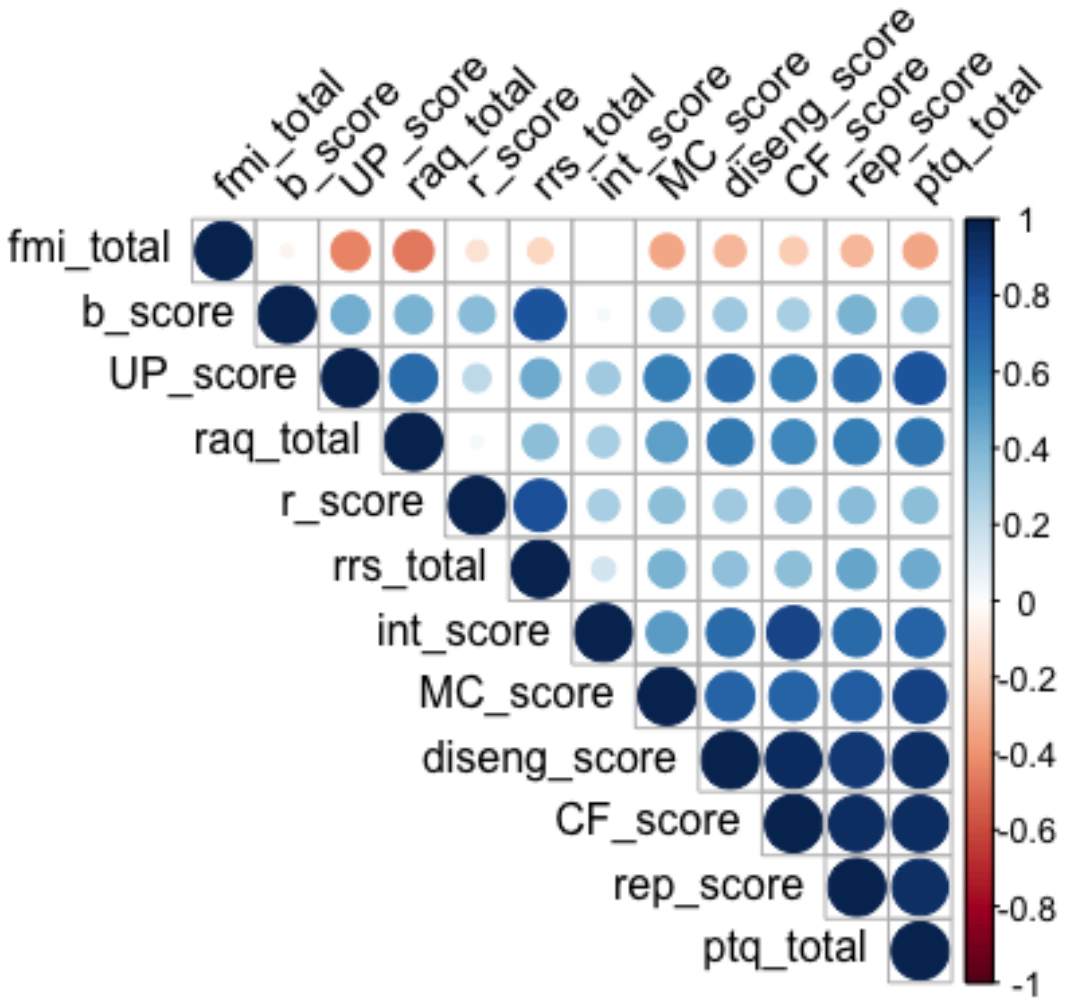


Figure 5. Graphical representation of correlation of main scores in Male Gender with significance levels

[*p-value<0.05 - *; p-value<0.01 - **; p-value<0.001 - ***;* **ABBREVIATIONS:** ***fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist*]

FEMALE GENDER (n=30)

	1	2	3	4	5	6	7	8	9	10	11
1. fmi_total											
2. rep_score	-.41*										
3. int_score	-0.34	.75**									
4. diseng_score	-.38*	.78**	.72**								
5. CF_score	-.41*	.93**	.89**	.92**							
6. UP_score	-.65**	.63**	.47**	.68**	.66**						
7. MC_score	-.45*	.85**	.71**	.82**	.88**	.65**					
8. ptq_total	-.51**	.92**	.83**	.92**	.98**	.78**	.92**				
9. r_score	-0.03	.54**	.58**	.52**	.59**	0.17	.56**	.54**			
10. b_score	-.55**	.61**	.64**	.66**	.70**	.65**	.67**	.74**	.48**		
11. rrs_total	-.41*	.75**	.76**	.75**	.82**	.49**	.76**	.80**	.76**	.84**	
12. raq_total	-0.26	.62**	0.32	.55**	.55**	.41*	.49**	.55**	0.29	0.34	.43*

TABLE 10: *p-value<0.05 - *; p-value<0.01 - **; p-value<0.001 - ***;* **ABBREVIATIONS:** ***fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist*

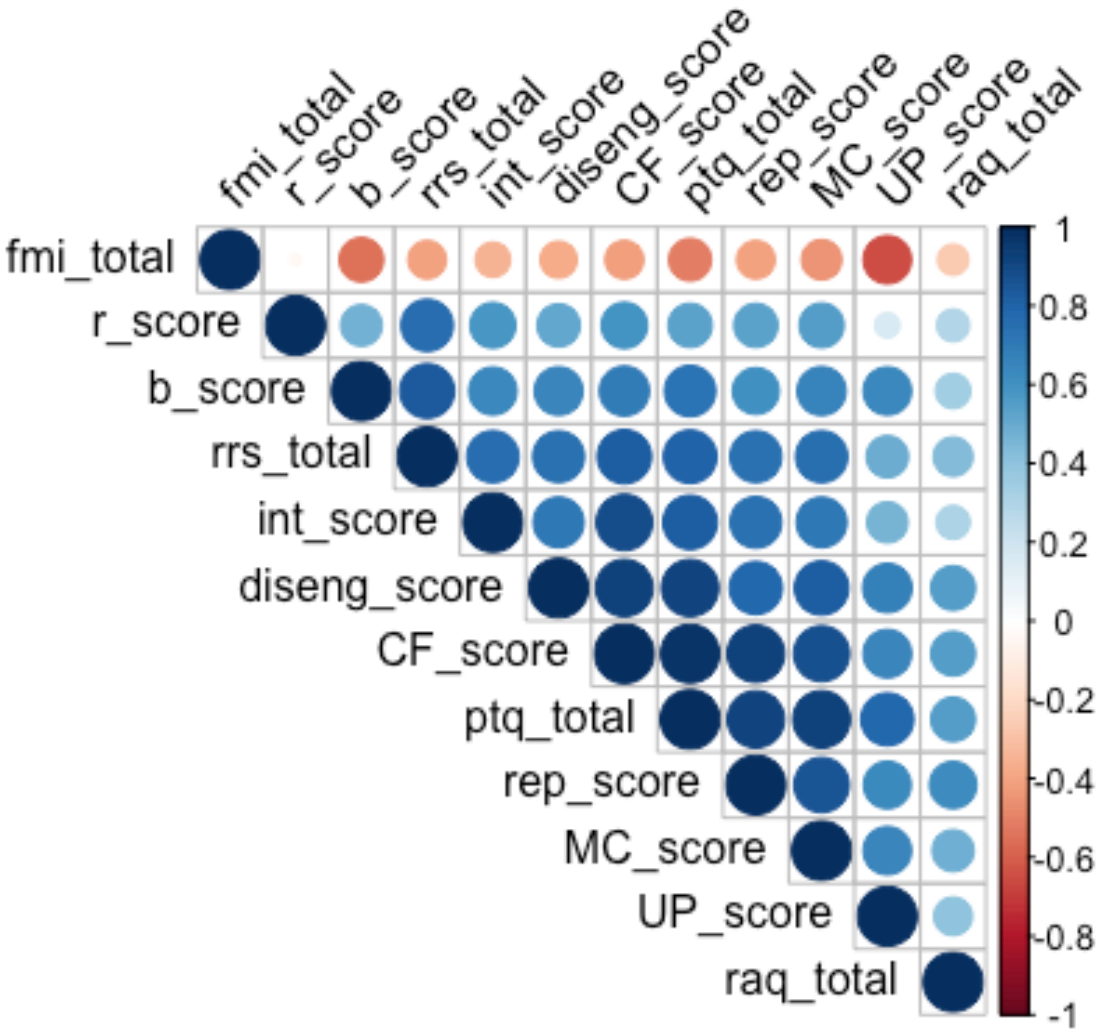


Figure 6. Graphical representation of correlation of main scores in Female Gender with significance levels

[*p-value<0.05 - *; p-value<0.01 - **; p-value<0.001 - ***;* **ABBREVIATIONS: *fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist]*

6.1.5. INDEPENDENT SAMPLE T-TESTS

	GROUP WISE			GENDER WISE		
	t	*df*	*p*	*t*	*df*	*p*
fmi_total	1.19	32.51	0.24	2.35	59	0.02*
rep_score	-0.68	39.31	0.50	-2.14	53.67	0.04*
int_score	-0.52	59	0.61	-1.48	59	0.14
diseng_score	-0.48	59	0.63	-0.95	59	0.35
CF_score	-0.62	59	0.54	-1.65	59	0.11
UP_score	-0.35	59	0.73	-0.14	59	0.89
MC_score	-0.09	59	0.93	-1.04	59	0.30
ptq_total	-0.49	59	0.62	-1.31	59	0.20
r_score	1.90	59	0.06	-0.66	59	0.51
b_score	-0.27	59	0.78	-1.46	59	0.15
rrs_total	-0.03	59	0.98	-0.88	59	0.38
raq_total	-1.59	59	0.12	-1.74	59	0.09

TABLE 11: *p-value<0.05 - *; p-value<0.01 - **; p-value<0.001 - ***;* **ABBREVIATIONS:** ***fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist*

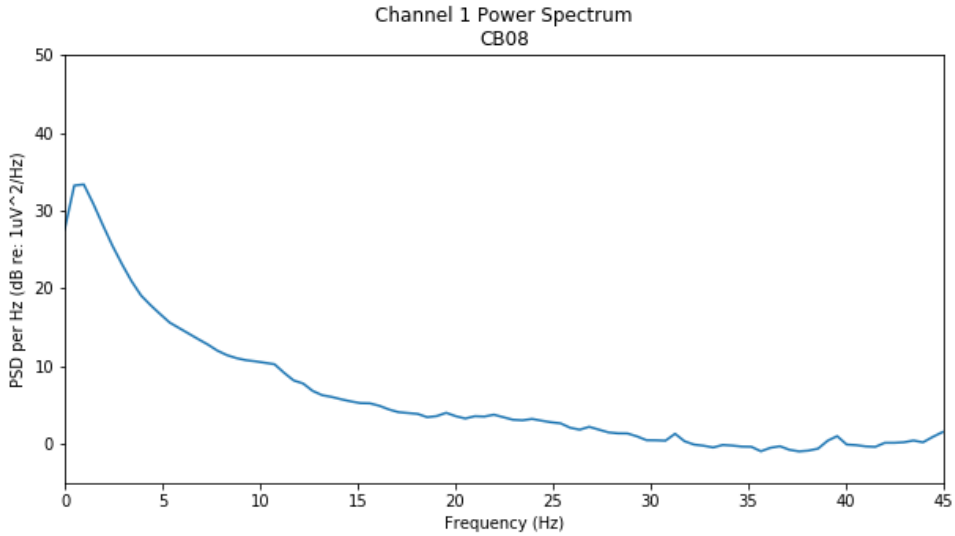
6.1.6. ACHIEVED EFFECT SIZE AND POWER

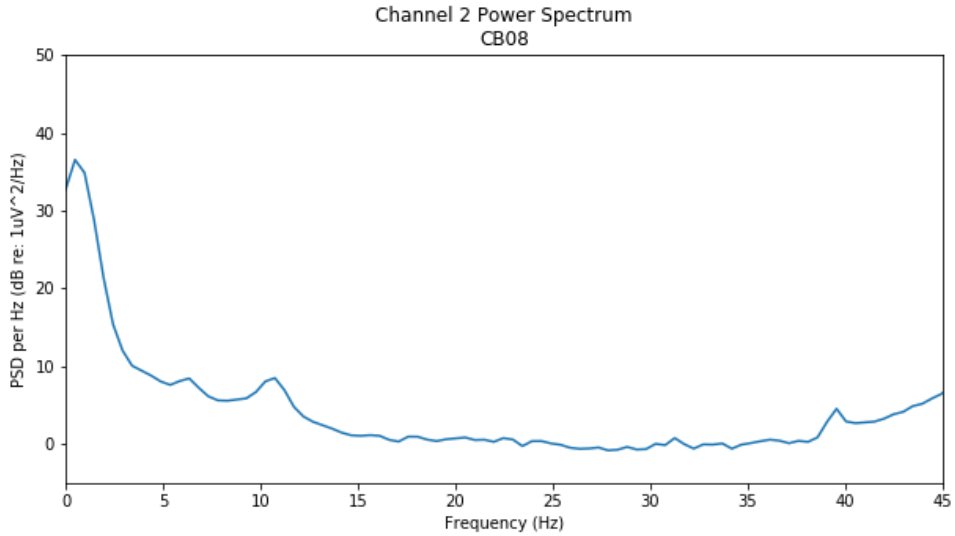
	GROUP WISE		GENDER WISE	
	EFFECT SIZE	**ACHIEVED POWER (1-β)**	**EFFECT SIZE**	**ACHIEVED POWER (1-β)**
fmi_total	0.33	0.23	0.60	0.64
rep_score	0.18	0.11	0.55	0.55
int_score	0.13	0.08	0.38	0.31
diseng_score	0.12	0.07	0.24	0.15
CF_score	0.16	0.09	0.42	0.37
UP_score	0.09	0.06	0.03	0.05
MC_score	0.02	0.05	0.27	0.18
ptq_total	0.13	0.08	0.33	0.25
r_score	0.50	0.46	0.17	0.25
b_score	0.07	0.06	0.37	0.30
rrs_total	0.01	0.05	0.23	0.14
raq_total	0.41	0.33	0.45	0.40

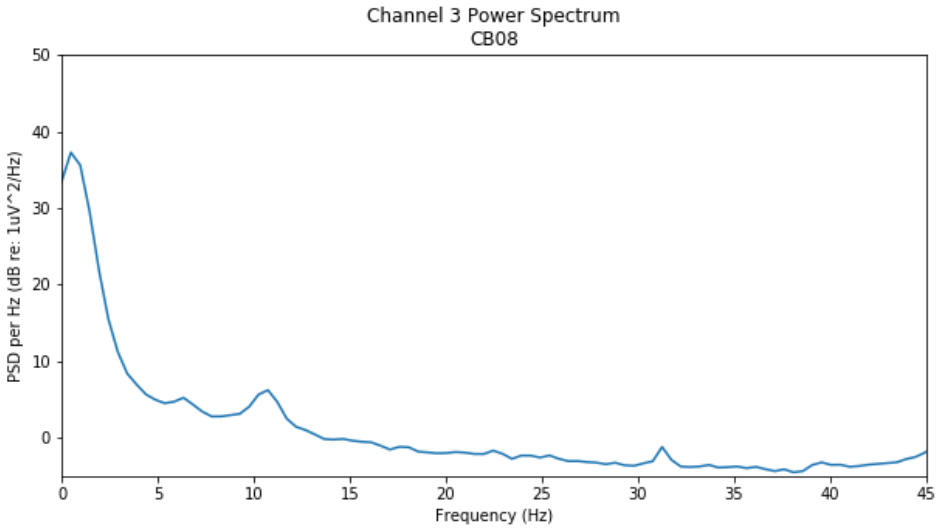
TABLE 12: ABBREVIATIONS: ***fmi_total*** *- total score of Freiburg Mindfulness Inventory;* ***rep_score*** *- score for repetitiveness in Perseverative Thinking Questionnaire;* ***int_score*** *- score for intrusiveness in Perseverative Thinking Questionnaire;* ***diseng_score*** *- score for difficulty to disengage in Perseverative Thinking Questionnaire;* ***CF_score*** *- score for core features of repetitive negative thought in Perseverative Thinking Questionnaire;* ***UP_score*** *- score for unproductiveness in Perseverative Thinking Questionnaire;* ***MC_score*** *- score for mental capacity in Perseverative Thinking Questionnaire;* ***r_score*** *- reflection score in Ruminative Response Scale;* ***b_score*** *- brooding score in Ruminative Response Scale;* ***rrs_total*** *- total score of Ruminative Response Scale;* ***raq_total*** *- total score for Rumination Assessment Checklist*

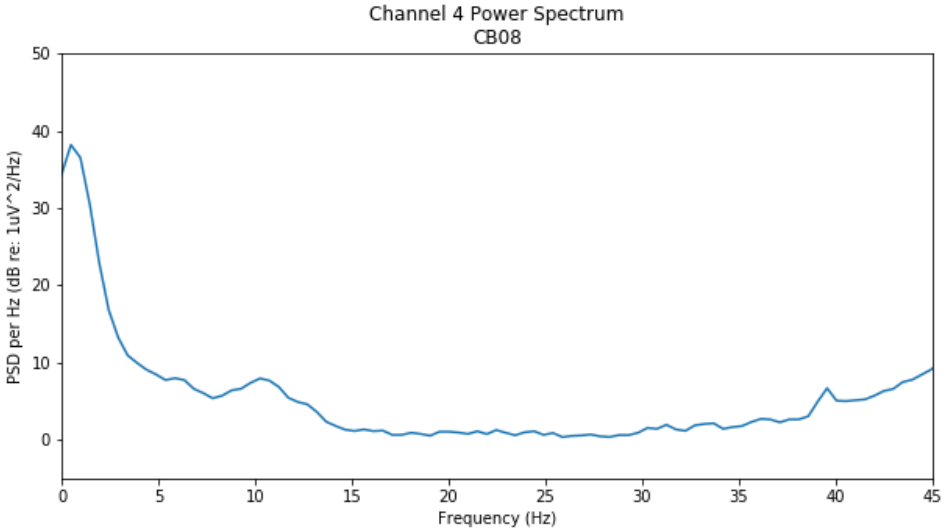
6.2. EEG DATA

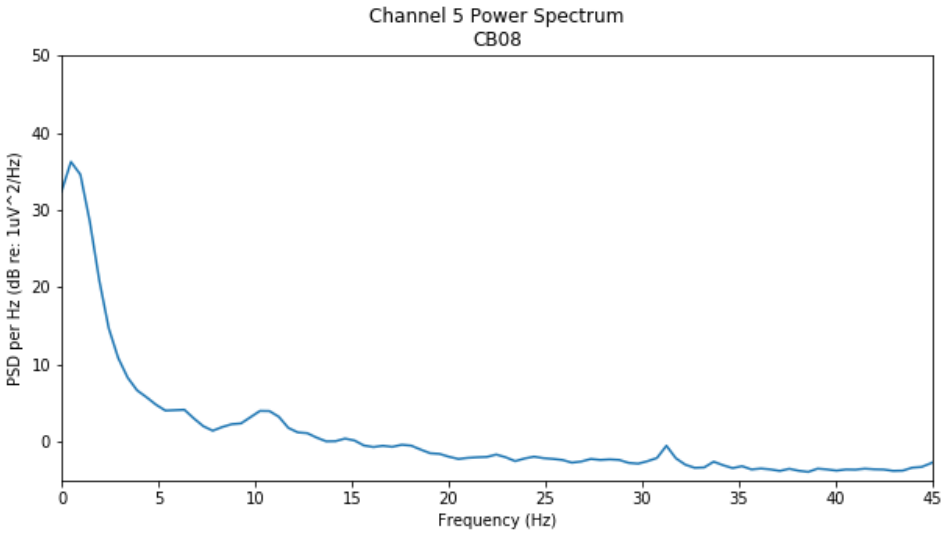
As a preliminary analysis, the power spectrums were generated using *EEGrunt* for each channel each reading for both yoga and non-yoga practitioners. A sample of generated spectrograms are shown below.

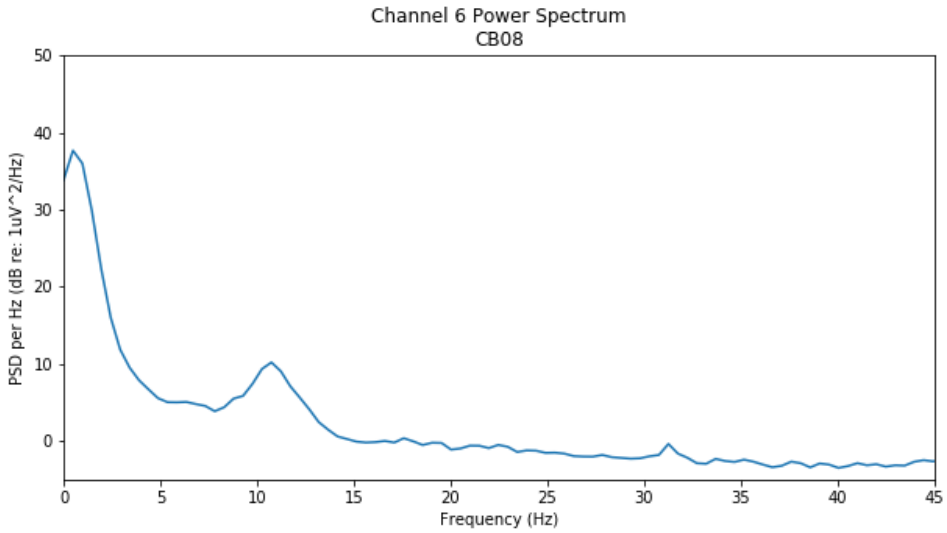


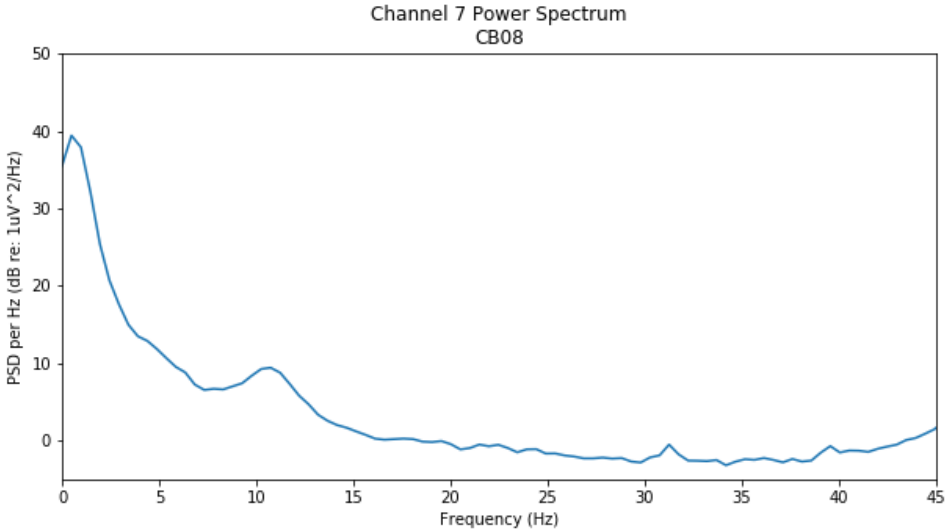


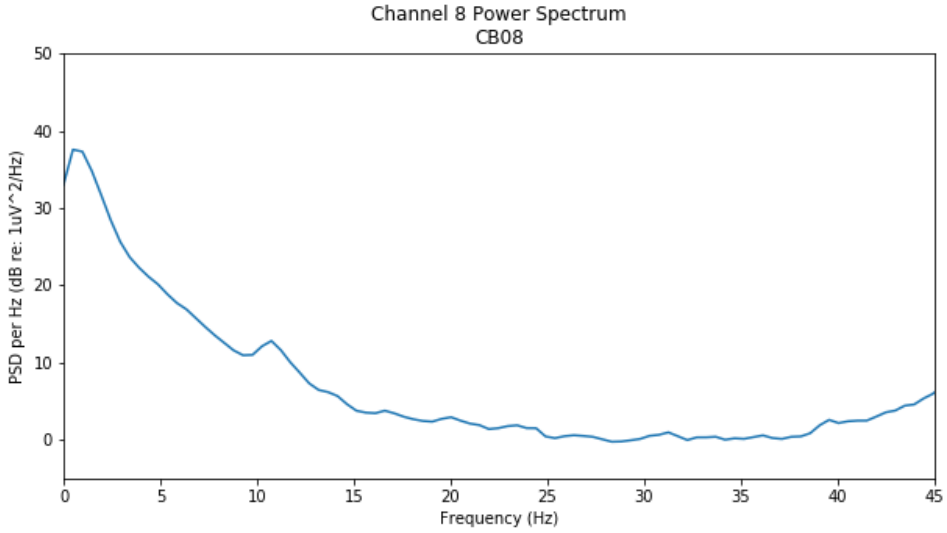

Channel 3 Power Spectrum
CB08
PSD per Hz (dB re: 1uV^2/Hz)
Frequency (Hz)
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45

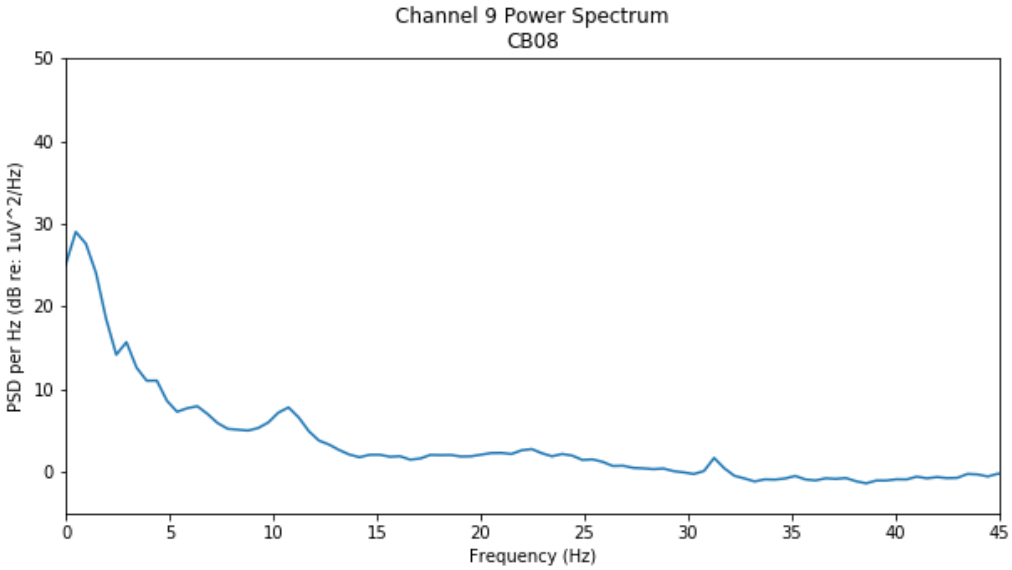

Channel 4 Power Spectrum
CB08
PSD per Hz (dB re: 1uV^2/Hz)
Frequency (Hz)
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45

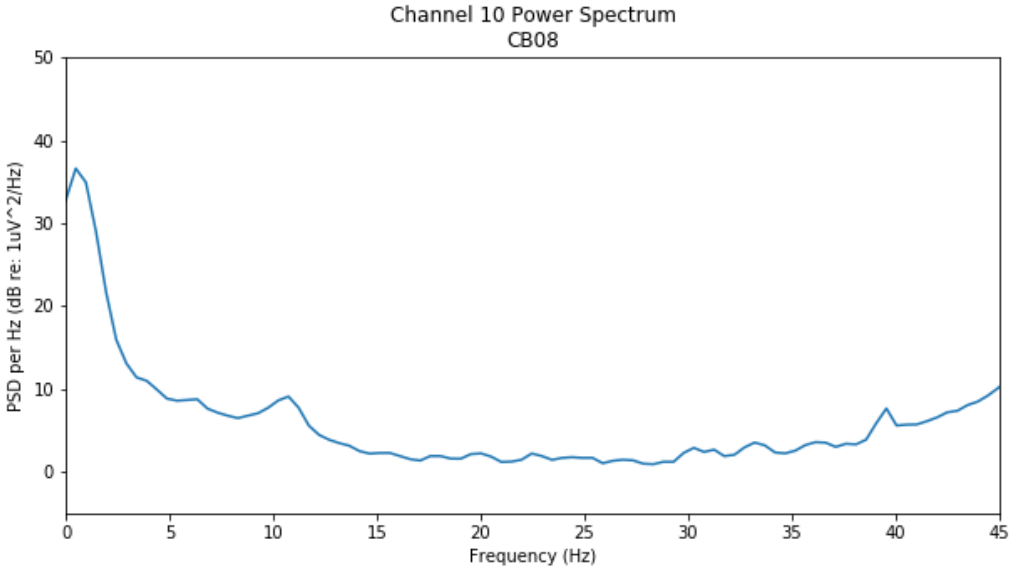

Channel 5 Power Spectrum
CB08
PSD per Hz (dB re: 1uV^2/Hz)
Frequency (Hz)
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45

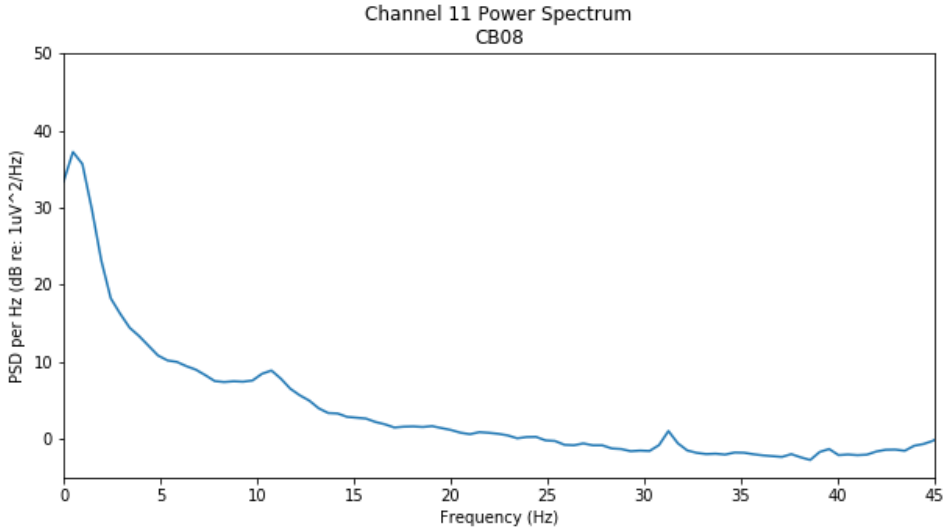

Channel 6 Power Spectrum
CB08
PSD per Hz (dB re: 1uV^2/Hz)
Frequency (Hz)
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45

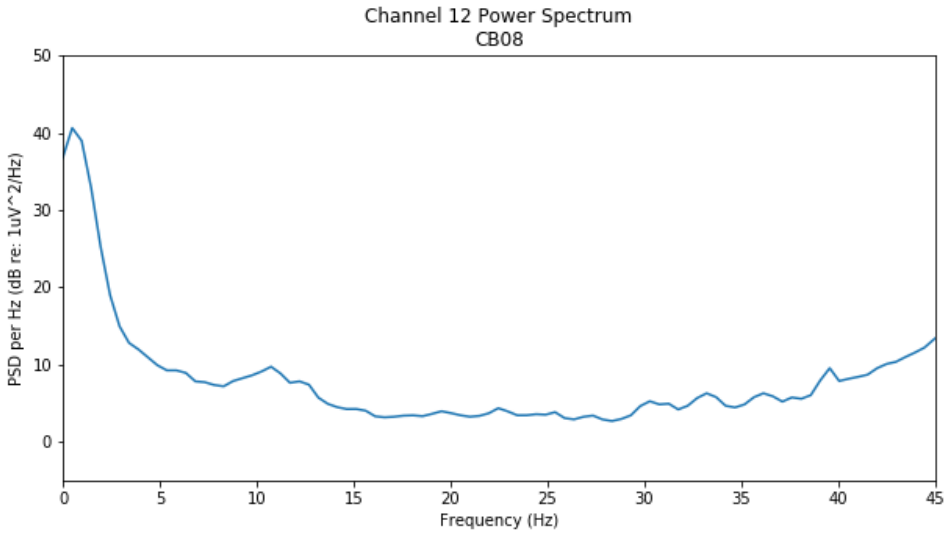

Channel 7 Power Spectrum
CB08
PSD per Hz (dB re: 1uV^2/Hz)
Frequency (Hz)
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45

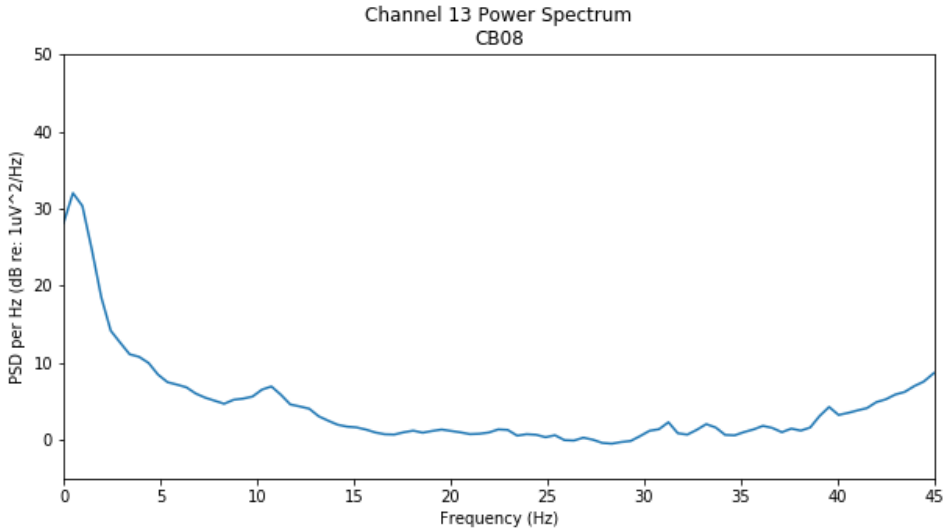

Channel 8 Power Spectrum
CB08
PSD per Hz (dB re: 1uV^2/Hz)
Frequency (Hz)
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45

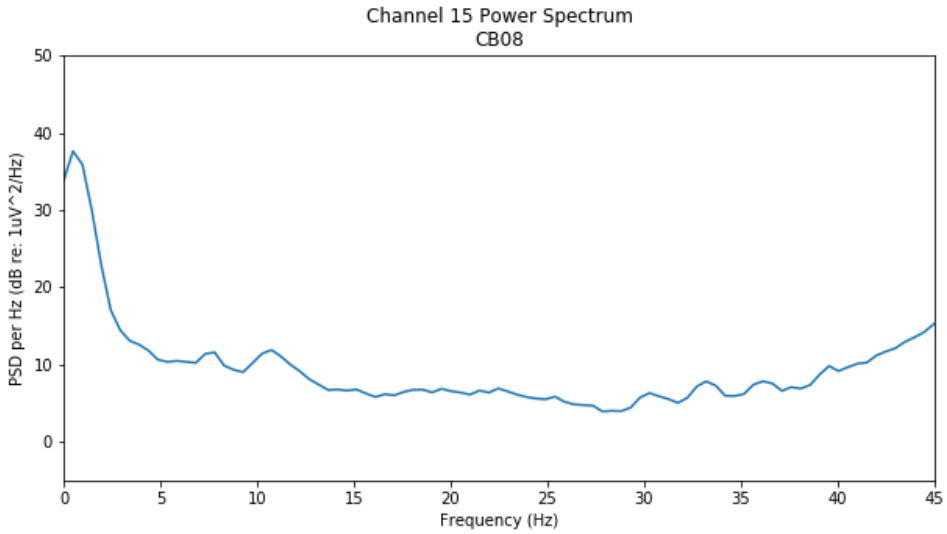

Channel 9 Power Spectrum
CB08
PSD per Hz (dB re: 1uV^2/Hz)
Frequency (Hz)
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45

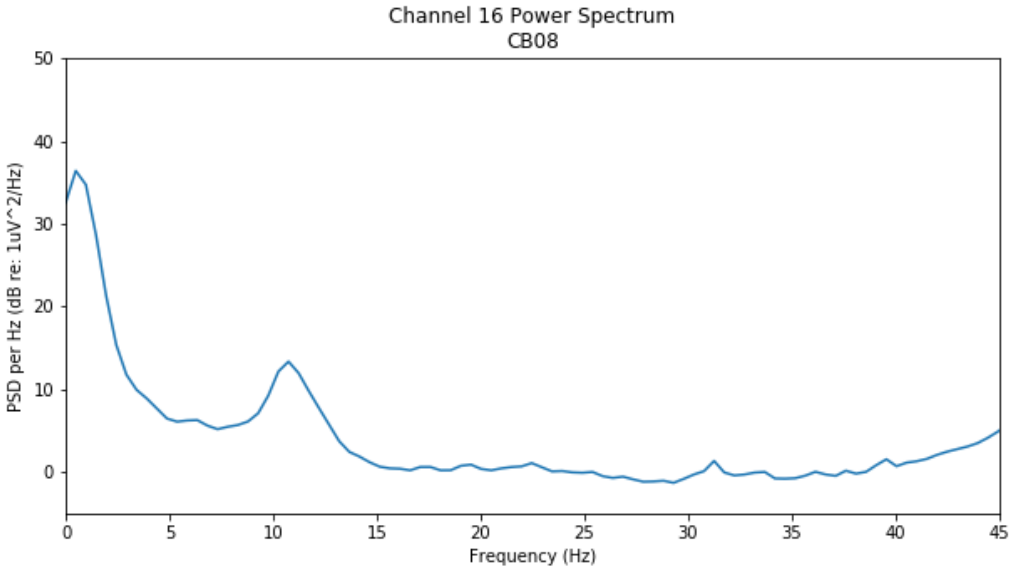

Channel 10 Power Spectrum
CB08
PSD per Hz (dB re: 1uV^2/Hz)
Frequency (Hz)
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45


Channel 11 Power Spectrum
CB08
PSD per Hz (dB re: 1uV^2/Hz)
Frequency (Hz)
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45


Channel 12 Power Spectrum
CB08
PSD per Hz (dB re: 1uV^2/Hz)
Frequency (Hz)
0
10
20
30
40
50
0
5
10
15
20
25
30
35
40
45


Channel 13 Power Spectrum
CB08
PSD per Hz (dB re: 1uV^2/Hz)
Frequency (Hz)
0
10
20
30
40
50
0
5
10
15
20
25
30
35
40
45


Channel 15 Power Spectrum
CB08
PSD per Hz (dB re: 1uV^2/Hz)
Frequency (Hz)
0
10
20
30
40
50
0
5
10
15
20
25
30
35
40
45



All the generated power spectrums were analysed group-wise for dominant frequencies across each channel at baseline and during rumination. The results were as follows:

EEG CHANNELS	YOGA PRACTITIONERS					NON-YOGA PRACTITIONERS				
	BASELINE	BASELINE %	RUMINATION	RUMINATION %	% CHANGE	BASELINE	BASELINE%	RUMINATION	RUMINATION %	% CHANGE
1	ALPHA	42.11	ALPHA	34.21	18.75	ALPHA	47.83	ALPHA	52.17	-9.09
2	ALPHA	47.37	ALPHA	39.47	16.67	ALPHA	69.57	ALPHA	56.52	18.75
3	ALPHA	31.58	ALPHA	34.21	-8.33	ALPHA	47.83	ALPHA	39.13	18.18
4	ALPHA	50.00	ALPHA	28.95	42.11	ALPHA	60.87	ALPHA	47.83	21.43
5	ALPHA	36.84	ALPHA	31.58	14.29	ALPHA	30.43	ALPHA	30.43	0.00
6	ALPHA	50.00	ALPHA	44.74	10.53	ALPHA	47.83	ALPHA	43.48	9.09
7	ALPHA	36.84	ALPHA	36.84	0.00	ALPHA	56.52	ALPHA	47.83	15.38
8	ALPHA	50.00	ALPHA	39.47	21.05	ALPHA	56.52	ALPHA	47.83	15.38
9	ALPHA	44.74	ALPHA	44.74	0.00	ALPHA	60.87	ALPHA	47.83	21.43
10	ALPHA	36.84	ALPHA	36.84	0.00	ALPHA	47.83	ALPHA	39.13	18.18
11	ALPHA	44.74	ALPHA	42.11	5.88	ALPHA	43.48	ALPHA	47.83	-10.00
12	ALPHA	42.11	ALPHA	44.74	-6.25	ALPHA	34.78	ALPHA	26.09	25.00
13	ALPHA	47.37	ALPHA	44.74	5.56	ALPHA	47.83	ALPHA	39.13	18.18
14	ALPHA	60.53	ALPHA	52.63	13.04	ALPHA	52.17	ALPHA	47.83	8.33
15	ALPHA	42.11	ALPHA	39.47	6.25	ALPHA	43.48	ALPHA	30.43	30.00
16	ALPHA	44.74	ALPHA	42.11	5.88	ALPHA	56.52	ALPHA	60.87	-7.69

TABLE 13: ***Baseline %*** *- % presence of particular frequency across all subjects at baseline.* ***Rumination %*** *- % presence of particular frequency across all subjects during rumination.* ***% Change*** *(from baseline to rumination).*

7. DISCUSSION

7.1. INTRODUCTION

The primary objective of this study was to characterise the EEG signatures for perseverative cognition. The secondary objective was to compare the EEG signatures for perseverative cognition for yoga and non-yoga practitioners.

7.2. MEASURES OF PERSEVERATIVE COGNITION

All the questionnaires used in the study were found to be reliable.

From Table 7, it can be inferred that there was significant correlation between all the main scores within yoga practitioners except trait and state rumination.

From Table 8, it can be inferred that there was significant correlation between all the main scores within non- yoga practitioners except trait mindfulness with core features of repetitive negative thought(RNT) (repetitiveness, intrusiveness, difficulties with disengagement), reflection(an aspect of trait rumination) and state rumination.

As shown in Table 9 & 10, it can be inferred that there were overall more significant correlations between the main scores within the female group as compared to the male group. Moreover, in both genders, there was no correlation of intrusiveness and reflection with both, trait mindfulness and state rumination. Reflection was also not correlated to unproductiveness.

Through the independent sample t-tests between the main score (shown in table 11), only trait mindfulness [$t(59) = 2.35$, $p<0.05$] and repetitiveness [$t(53.67) = -2.14$, $p<0.05$] showed a significant change across the male and female groups.

Almost all the measures showed a considerable effect size but the overall achieved power of the study is not sufficient, possibly due to the low sample size.

7.3. EEG & PERSEVERATIVE COGNITION

From the EEG data analysis in table 13, it was observed that alpha was the dominant frequency across both yoga and non-yoga practitioners and across the baseline and

rumination readings. Moreover, in comparison yoga practitioners, non-yoga practitioners showed higher levels of rumination. Also, yoga practitioners showed lower changes in brain wave activity compared to the non- yoga practitioners.

8. APPRAISAL

8.1. STRENGTHS OF THE STUDY

This is the first study of its kind that has been done to objectively characterise perseverative cognition through EEG and moreover, compare these EEG signatures for yoga and non-yoga practitioners.

8.2. LIMITATIONS OF THE STUDY

- The recruited subjects have come from versatile professions such as job, service, and business for long term courses. For consistent results, all students should belong to student's category.
- The procedure for EEG recording could be made more standardised to reduce artefacts.
- The procedure for rumination could be refined further to induce uniform rumination across all subjects.
- Better EEG data could be obtained with more number of channels.
- The analysis done for EEG data - power spectrum analysis - in this study is very preliminary and gross in nature and may not be sufficient to understand such a subtle cognitive process as perseverative cognition.

8.3. FUTURE SCOPE FOR RESEARCH

- Further analysis of the EEG data could be done different methods such as non-linear domains, correlation dimension, fractal dimension, largest Lyapunov entropy, approximate entropy, Hurst exponent, phase space plot and recurrence plots.
- An attempt could be made to assess large differences in EEG signals by recruiting only those subjects that score <15 or >45 on the perseverative thinking questionnaire.
- Nostril predominance is also known to increase the EEG spectral power in the contralateral hemisphere. Hence, EEG readings could be taken after subjects could do forceful breathing in the non-patent nostril so that both nostrils become patent.

- Higuchi fractal dynamics analysis algorithm might be helpful as an to ascertain the EEG signal complexity. Greater cognitive load is expected to have a greater Higuchi fractal number.

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10. APPENDICES

10.1. APPENDIX A - INFORMED CONSENT

1) **Participant Informed Consent**

Swami Vivekananda Yoga Anusandhana Samsthana, Bangalore
Study title: Characterising human EEG signatures in varying levels of Perseverative Thinking
Principal Investigators: Dr. Judu Ilavarasu, Dr. Ragavendrasamy and Dr. Rajesh S K
S-VYASA, Bangalore. (Phone No: 080-22639906)

This study aims to identify EEG signatures representing perseverative cognition and also to understand the characteristics of EEG signatures representing perseverative cognition in yoga and non-yoga practitioners. This would help in developing better and precise tool to measure a person's perseverative cognition. These assessments consist of a demographic sheet followed by a set of questionnaires to be filled on the computer alongwith EEG assessments. The whole session may take approximately 40 minutes.
No incentives will be provided for participating in this study. However, if you wish results of your test scores will be sent to you through e-mail. Your valuable participation would help develop an objective quantification tool for a subjective phenomenon - Perseverative Cognition, which is of high practical application and will contribute to the field of yoga and psychology research.

No potential risks are anticipated by undergoing these tests. However, discomfort will not exceed minimal risk. You are free to express any discomfort or problem during your test session to the test administrator. You are free to withdraw your participation at any point of the study without penalty.

This assessment session is coded. In demographic sheet, giving your name is optional. If you need your results, you may provide your e-mail ID. No other sensitive information is collected. All information obtained in this study is strictly confidential unless disclosure is required by law.

Voluntary Consent by Participant

○ **I agree** ○ **I do not agree**

I agree that I have read this informed consent fully. I fully understand the contents of this document and am openly willing to consent to take part in this study. I am 18 years of age or older and am agreeing to participate in this study voluntarily. All the queries related to my participation were clarified to me and in ca Confirm y problem or further clarification I may contact the above mentioned persons.

10.2. APPENDIX B - DEMOGRAPHICS QUESTIONNAIRE

Please answer the following demographic questions

1). Name

2). Age

3). Gender

- Male
- Female

4). E-mail ID

5). Relationship Status

- Ever Married
- Never Married

6). Education

- School
- Undergraduate
- Postgraduate

7). Do you have earlier experience of yoga practice?

- Yes
- No

8). How many hours in a week do you practice yoga?

9). Do you currently have any stressful event in your life?

- Yes
- No

10). Please indicate level of stress.

1. Not al all 2 3 4 5 6 7. Very much

10.3. APPENDIX C - FREIBURG MINDFULNESS INVENTORY

Freiburg Mindfulness Inventory

Description:

The FMI is a useful, valid and reliable questionnaire for measuring mindfulness. It is most suitable in generalized contexts, where knowledge of the Buddhist background of mindfulness cannot be expected. The 14 items cover all aspects of mindfulness.

The purpose of this inventory is to characterize your experience of mindfulness. Please use the last ___ days as the time-frame to consider each item. Provide an answer the for every statement as best you can. Please answer as honestly and spontaneously as possible. There are neither 'right' nor 'wrong' answers, nor 'good' or 'bad' responses. What is important to us is your own personal experience.

1	2	3	4
Rarely	Occasionally	Fairly often	Almost always

I am open to the experience of the present moment.	1	2	3	4
I sense my body, whether eating, cooking, cleaning or talking.	1	2	3	4
When I notice an absence of mind, I gently return to the experience of the here and now.	1	2	3	4
I am able to appreciate myself.	1	2	3	4
I pay attention to what's behind my actions.	1	2	3	4
I see my mistakes and difficulties without judging them.	1	2	3	4
I feel connected to my experience in the here-and-now.	1	2	3	4
I accept unpleasant experiences.	1	2	3	4
I am friendly to myself when things go wrong.	1	2	3	4
I watch my feelings without getting lost in them.	1	2	3	4
In difficult situations, I can pause without immediately reacting.	1	2	3	4
when things get hectic and stressful.				
I am impatient with myself and with others.	1	2	3	4
I am able to smile when I notice how I sometimes make life difficult.	1	2	3	4

10.4. APPENDIX D - PERSEVERATIVE THINKING QUESTIONNAIRE

Instruction: In this questionnaire, you will be asked to describe how you *typically* think about negative experiences or problems. Please read the following statements and rate the extent to which they apply to you when you think about negative experiences or problems.

		never	**rarely**	**sometimes**	**often**	**almost always**
1.	The same thoughts keep going through my mind again and again.	0	1	2	3	4
2.	Thoughts intrude into my mind.	0	1	2	3	4
3.	I can’t stop dwelling on them.	0	1	2	3	4
4.	I think about many problems without solving any of them.	0	1	2	3	4
5.	I can’t do anything else while thinking about my problems.	0	1	2	3	4
6.	My thoughts repeat themselves.	0	1	2	3	4
7.	Thoughts come to my mind without me wanting them to.	0	1	2	3	4

8.	I get stuck on certain issues and can't move on.	0	1	2	3	4
9.	I keep asking myself questions without finding an answer.	0	1	2	3	4
10.	My thoughts prevent me from focusing on other things.	0	1	2	3	4
11.	I keep thinking about the same issue all the time.	0	1	2	3	4
12.	Thoughts just pop into my mind.	0	1	2	3	4
13.	I feel driven to continue dwelling on the same issue.	0	1	2	3	4
14.	My thoughts are not much help to me.	0	1	2	3	4
15.	My thoughts take up all my attention.	0	1	2	3	4

10.5. APPENDIX E - RUMINATIVE RESPONSE SCALE

Rumination Scale

People think and do many different things when they feel depressed. Please read each of the items below and indicate whether you almost never, sometimes, often, or almost always think or do each one when you feel down, sad, or depressed. Please indicate what you generally do, not what you think you should do.

1 almost never 2 sometimes 3 often 4 almost always

1. think about how alone you feel
2. think “I won’t be able to do my job if I don’t snap out of this”
3. think about your feelings of fatigue and achiness
4. think about how hard it is to concentrate
5. think “What am I doing to deserve this?”
6. think about how passive and unmotivated you feel.
7. analyze recent events to try to understand why you are depressed
8. think about how you don’t seem to feel anything anymore
9. think “Why can’t I get going?”
10. think “Why do I always react this way?”
11. go away by yourself and think about why you feel this way
12. write down what you are thinking about and analyze it
13. think about a recent situation, wishing it had gone better
14. think “I won’t be able to concentrate if I keep feeling this way.”
15. think “Why do I have problems other people don’t have?”
16. think “Why can’t I handle things better?”
17. think about how sad you feel.
18. think about all your shortcomings, failings, faults, mistakes
19. think about how you don’t feel up to doing anything
20. analyze your personality to try to understand why you are depressed
21. go someplace alone to think about your feelings
22. think about how angry you are with yourself

10.6. APPENDIX F - RUMINATIVE ASSESSMENT CHECKLIST

RUMINATIVE ASSESSMENT CHECKLIST

Directions: Please consider your thoughts and feelings about this session and use the scale to answer the following questions.

1). In regard to this session, were your thoughts positive, negative or neutral?

1. Positive 2 3 4. Neutral 5 6 7. Negative

2). To what extent were you able to indulge in your repetitive thoughts in this session?

1. Not al all 2 3 4 5 6 7. Very much

3). How stressed were you during the thought process?

1. Not al all 2 3 4 5 6 7. Very much

4). How depressed did you feel during the thought process?

1. Not al all 2 3 4 5 6 7. Very much

5). How often do these thoughts occur to you?

1. Never 2 3 4. Sometimes 5 6 7. Very often

10.7. APPENDIX G - RAW DATA

group	subject	age	gender	relationship	education	yp	ypt	se	lse	fmi_total	rep_score	int_score	dseng_score	CF_score	UP_score	MC_score	ptq_total	r_score	b_score	rrs_total	raq_total
1	1	21	1	2	2	1	6	2	2	38	4	3	3	13	3	6	22	12	7	38	8
1	2	22	1	2	2	1	2	1	5	49	5	3	3	13	5	2	20	15	10	56	13
1	3	24	1	2	3	1	5	1	5	50	5	3	3	14	5	3	22	9	11	43	14
1	4	22	2	2	2	1	4	1	5	31	12	11	11	35	11	9	55	18	18	78	17
1	5	22	2	2	2	1	3	2	1	41	6	7	7	21	5	6	32	8	9	39	21
1	6	25	1	2	2	1	5	1	4	31	8	9	9	26	8	8	42	10	8	43	26
1	7	24	2	2	2	1	7	2	3	45	5	3	3	12	3	6	21	11	13	51	18
1	8	22	2	2	2	1	4	2	1	43	3	3	3	12	3	2	17	10	7	32	12
1	9	23	2	2	2	1	5	2	1	41	4	3	3	10	5	4	19	6	7	27	12
1	10	42	1	2	3	1	4	1	3	40	6	6	6	18	6	6	30	11	10	50	20
1	11	22	1	2	2	1	15	1	4	43	4	4	4	11	6	6	23	7	12	43	22
1	12	23	1	2	2	1	6	2	2	45	4	3	3	11	4	5	20	11	10	42	14
1	13	20	1	2	2	2	1	2	1	47	4	3	3	14	1	2	17	5	6	25	16
1	14	30	2	2	3	1	8	2	2	40	5	3	3	12	3	3	18	10	6	32	21
1	15	23	2	2	3	1	7	1	3	44	8	5	5	21	4	5	30	15	12	49	23
1	16	22	2	2	3	1	6	2	3	47	6	2	2	15	2	5	22	17	11	56	16
1	17	22	1	2	3	1	12	1	3	44	5	7	7	18	9	6	33	9	8	38	17
1	18	28	1	1	3	1	12	2	1	45	4	4	4	13	2	2	17	7	7	27	11
1	19	34	1	2	3	1	7	1	3	41	7	7	7	19	7	4	30	12	14	51	23
1	20	23	1	2	2	1	6	2	1	45	5	5	5	16	5	5	26	9	8	38	20

1	**21**	**28**	**1**	**2**	**3**	**1**	**7**	**2**	**2**	**39**	**5**	**4**	**4**	**13**	**4**	**5**	**22**	**12**	**16**	**56**	**15**
1	**22**	**22**	**1**	**2**	**3**	**1**	**1**	**2**	**1**	**43**	**6**	**6**	**6**	**17**	**3**	**4**	**24**	**11**	**9**	**41**	**15**
1	**23**	**22**	**2**	**2**	**3**	**1**	**15**	**2**	**2**	**43**	**3**	**3**	**3**	**9**	**5**	**4**	**18**	**12**	**8**	**38**	**13**
1	**24**	**22**	**1**	**2**	**3**	**1**	**15**	**2**	**1**	**42**	**2**	**2**	**2**	**7**	**1**	**1**	**9**	**12**	**8**	**43**	**11**
1	**25**	**24**	**1**	**2**	**3**	**1**	**7**	**2**	**4**	**43**	**4**	**3**	**3**	**12**	**3**	**4**	**19**	**14**	**12**	**57**	**14**
1	**26**	**24**	**2**	**2**	**2**	**1**	**7**	**1**	**5**	**34**	**9**	**5**	**5**	**23**	**7**	**8**	**38**	**10**	**13**	**44**	**17**
1	**27**	**25**	**2**	**2**	**3**	**1**	**6**	**2**	**4**	**29**	**10**	**9**	**9**	**28**	**9**	**9**	**46**	**13**	**17**	**57**	**26**
1	**28**	**27**	**1**	**2**	**3**	**1**	**7**	**2**	**4**	**43**	**4**	**2**	**2**	**10**	**4**	**5**	**19**	**11**	**9**	**43**	**19**
1	**29**	**24**	**1**	**2**	**2**	**1**	**12**	**2**	**2**	**47**	**8**	**6**	**6**	**24**	**5**	**6**	**35**	**16**	**12**	**62**	**16**
1	**30**	**41**	**2**	**2**	**3**	**1**	**6**	**2**	**4**	**39**	**5**	**5**	**5**	**18**	**3**	**6**	**27**	**12**	**11**	**48**	**18**
1	**31**	**22**	**1**	**2**	**2**	**1**	**10**	**2**	**2**	**41**	**8**	**9**	**9**	**26**	**4**	**10**	**40**	**16**	**6**	**46**	**17**
1	**32**	**25**	**2**	**2**	**3**	**1**	**6**	**1**	**3**	**43**	**11**	**8**	**8**	**27**	**8**	**8**	**43**	**10**	**12**	**50**	**28**
1	**33**	**22**	**2**	**2**	**3**	**1**	**3**	**2**	**3**	**30**	**6**	**5**	**5**	**17**	**5**	**4**	**26**	**10**	**12**	**44**	**21**
1	**34**	**22**	**2**	**2**	**3**	**1**	**7**	**1**	**5**	**42**	**8**	**10**	**10**	**25**	**5**	**8**	**38**	**14**	**14**	**66**	**24**
1	**35**	**24**	**1**	**2**	**3**	**1**	**12**	**2**	**2**	**43**	**8**	**6**	**6**	**21**	**10**	**8**	**39**	**13**	**14**	**54**	**20**
1	**36**	**42**	**2**	**2**	**3**	**1**	**14**	**2**	**3**	**48**	**5**	**3**	**3**	**14**	**2**	**3**	**19**	**11**	**10**	**44**	**21**
1	**37**	**21**	**2**	**2**	**2**	**1**	**7**	**2**	**2**	**37**	**3**	**2**	**2**	**8**	**1**	**1**	**10**	**10**	**11**	**42**	**20**
1	**38**	**20**	**2**	**2**	**2**	**1**	**12**	**1**	**5**	**43**	**8**	**8**	**8**	**23**	**5**	**7**	**35**	**17**	**13**	**60**	**16**
2	**1**	**39**	**2**	**1**	**3**	**1**	**0**	**1**	**7**	**21**	**12**	**12**	**12**	**34**	**10**	**12**	**56**	**16**	**15**	**75**	**35**
2	**2**	**40**	**1**	**2**	**3**	**1**	**0**	**2**	**3**	**44**	**4**	**4**	**4**	**15**	**5**	**6**	**26**	**13**	**10**	**49**	**17**
2	**3**	**23**	**2**	**2**	**2**	**1**	**1**	**1**	**5**	**46**	**7**	**5**	**5**	**18**	**2**	**6**	**26**	**13**	**10**	**45**	**24**
2	**4**	**24**	**2**	**2**	**2**	**1**	**0**	**1**	**3**	**27**	**10**	**7**	**7**	**25**	**6**	**10**	**41**	**12**	**14**	**58**	**18**
2	**5**	**22**	**2**	**2**	**2**	**1**	**0**	**1**	**4**	**47**	**9**	**10**	**10**	**26**	**6**	**6**	**38**	**13**	**10**	**47**	**31**
2	**6**	**23**	**2**	**2**	**3**	**2**	**0**	**2**	**2**	**47**	**2**	**1**	**1**	**7**	**1**	**0**	**8**	**7**	**5**	**25**	**12**

2	**7**	**23**	**2**	**2**	**2**	**2**	**0**	**2**	**4**	**31**	**3**	**6**	**6**	**16**	**9**	**4**	**29**	**7**	**18**	**51**	**17**
2	**8**	**22**	**2**	**2**	**2**	**2**	**0**	**2**	**4**	**32**	**8**	**2**	**2**	**14**	**7**	**3**	**24**	**6**	**10**	**43**	**26**
2	**9**	**21**	**2**	**1**	**2**	**1**	**0**	**2**	**1**	**30**	**5**	**3**	**3**	**12**	**5**	**4**	**21**	**8**	**9**	**34**	**17**
2	**10**	**25**	**1**	**2**	**2**	**1**	**0**	**1**	**3**	**47**	**4**	**2**	**2**	**12**	**0**	**1**	**13**	**7**	**7**	**29**	**11**
2	**11**	**24**	**1**	**2**	**2**	**2**	**0**	**1**	**5**	**40**	**2**	**1**	**1**	**9**	**3**	**2**	**14**	**7**	**7**	**31**	**16**
2	**12**	**21**	**2**	**2**	**2**	**1**	**0**	**1**	**2**	**42**	**8**	**5**	**5**	**22**	**5**	**7**	**34**	**12**	**11**	**49**	**22**
2	**13**	**21**	**2**	**2**	**2**	**1**	**0**	**2**	**4**	**42**	**5**	**5**	**5**	**16**	**4**	**5**	**25**	**8**	**7**	**33**	**14**
2	**14**	**22**	**1**	**2**	**2**	**1**	**0**	**2**	**1**	**50**	**8**	**9**	**9**	**25**	**7**	**9**	**41**	**9**	**15**	**51**	**18**
2	**15**	**23**	**2**	**2**	**2**	**1**	**0**	**1**	**2**	**43**	**7**	**6**	**6**	**18**	**4**	**5**	**27**	**6**	**11**	**40**	**15**
2	**16**	**23**	**1**	**2**	**2**	**2**	**0**	**1**	**5**	**37**	**11**	**12**	**12**	**33**	**9**	**8**	**50**	**14**	**14**	**59**	**27**
2	**17**	**24**	**1**	**2**	**2**	**1**	**0**	**1**	**5**	**42**	**3**	**2**	**2**	**8**	**3**	**4**	**15**	**12**	**12**	**59**	**18**
2	**18**	**24**	**1**	**2**	**2**	**2**	**0**	**1**	**6**	**35**	**7**	**6**	**6**	**19**	**6**	**6**	**31**	**12**	**16**	**59**	**26**
2	**19**	**21**	**1**	**2**	**2**	**1**	**2**	**1**	**2**	**50**	**4**	**4**	**4**	**14**	**3**	**2**	**19**	**8**	**9**	**34**	**18**
2	**20**	**21**	**1**	**2**	**2**	**2**	**0**	**2**	**1**	**48**	**4**	**4**	**4**	**13**	**3**	**1**	**17**	**9**	**8**	**41**	**18**
2	**21**	**22**	**1**	**2**	**2**	**2**	**0**	**1**	**5**	**27**	**6**	**5**	**5**	**15**	**10**	**4**	**29**	**9**	**8**	**44**	**21**
2	**22**	**22**	**2**	**2**	**2**	**1**	**0**	**1**	**3**	**36**	**9**	**7**	**7**	**28**	**2**	**6**	**36**	**13**	**13**	**68**	**17**
2	**23**	**21**	**1**	**2**	**2**	**2**	**2**	**1**	**4**	**40**	**8**	**5**	**5**	**18**	**5**	**9**	**32**	**8**	**9**	**39**	**20**

VARIABLE	**MEANING**
yp	Earlier experience of yoga
ypt	Average hours of practicing yoga in a week
se	presence of stressful event in life currently
lse	level of stress at the moment
fmi	Freiburg Mindfulness Inventory
fmi_total	Total score of FMI
ptq	Perseverative Thinking Questionnaire
rep_score	Score for Repetitiveness in PTQ
int_score	Score for Intrusiveness in PTQ
diseng_score	Score for Difficulty to Disengage in PTQ
CF_score	Score for Core Features of Repetitive Negative Thought in PTQ
UP_score	Score for Unproductiveness in PTQ
MC_score	Score for Mental Capacity in PTQ

rrs	Ruminative Responses Scale
r_score	Reflection score in RRS
b_score	Brooding score in RRS
rrs_total	Total score of RRS
raq	Ruminative Assessment Questionnaire
raq_total	Total score for RAQ

10.8. APPENDIX H - CODES FOR R STUDIO

```
options(max.print=10000000)

#SUBSET FOR MAIN_SCORES OF mskt (master sheet)
main_scores<-subset(mskt[,c(25,41:47,70:72,78)])

#DESCRIPTIVE STATISTICS BY GROUP
describeBy(main_scores,mskt$group)
MS1<-describeBy(main_scores,mskt$gender)

#CRONBACH ALPHA
alpha(mskt[,11:24]) #FOR FMI
alpha(mskt[,26:40]) #FOR PTQ
alpha(mskt[,48:69]) #FOR RRS
alpha(mskt[,73:77]) #FOR RAC

#OUTLIER ANALYSIS FOR MAIN SCORES
grubbs.test(mskt$fmi_total,type = 11)
grubbs.test(mskt$ptq_total, type = 11)
grubbs.test(mskt$rrs_total,type = 11)
grubbs.test(mskt$raq_total,type = 11)

#CREATING SUBSETS
y<-subset(mskt,mskt$group=="1") #YOGA PRACTITIONERS
c<-subset(mskt,mskt$group=="2") #NON-YOGA PRACTITIONERS
m<-subset(mskt,mskt$gender=="1") #MALE SUBJECTS
f<-subset(mskt,mskt$gender=="2") #FEMALE SUBJECTS

#MEAN AGE FOR EACH GROUP
mean(y$age)
```

```
mean(c$age)
mean(m$age)
mean(f$age)

#MEAN SD FOR EACH GROUP
sd(y$age)
sd(c$age)
sd(m$age)
sd(f$age)

#NORMALITY TEST FOR MAIN SCORES IN EACH GROUP
shapiro.test(y$fmi_total)
shapiro.test(y$ptq_total)
shapiro.test(y$rrs_total)
shapiro.test(y$raq_total)
shapiro.test(y$rep_score)
shapiro.test(y$int_score)
shapiro.test(y$diseng_score)
shapiro.test(y$CF_score)
shapiro.test(y$UP_score)
shapiro.test(y$MC_score)
shapiro.test(y$r_score)
shapiro.test(y$b_score)

shapiro.test(c$fmi_total)
shapiro.test(c$ptq_total)
shapiro.test(c$rrs_total)
shapiro.test(c$raq_total)
shapiro.test(c$rep_score)
shapiro.test(c$int_score)
```

```
shapiro.test(c$diseng_score)
shapiro.test(c$CF_score)
shapiro.test(c$UP_score)
shapiro.test(c$MC_score)
shapiro.test(c$r_score)
shapiro.test(c$b_score)

shapiro.test(m$fmi_total)
shapiro.test(m$ptq_total)
shapiro.test(m$rrs_total)
shapiro.test(m$raq_total)
shapiro.test(m$rep_score)
shapiro.test(m$int_score)
shapiro.test(m$diseng_score)
shapiro.test(m$CF_score)
shapiro.test(m$UP_score)
shapiro.test(m$MC_score)
shapiro.test(m$r_score)
shapiro.test(m$b_score)

shapiro.test(f$fmi_total)
shapiro.test(f$ptq_total)
shapiro.test(f$rrs_total)
shapiro.test(f$raq_total)
shapiro.test(f$rep_score)
shapiro.test(f$int_score)
shapiro.test(f$diseng_score)
shapiro.test(f$CF_score)
shapiro.test(f$UP_score)
shapiro.test(f$MC_score)
```

```
shapiro.test(f$r_score)
shapiro.test(f$b_score)

#LEVENE'S TEST FOR MAIN SCORES ACROSS EACH GROUP
leveneTest(mskt$fmi_total,mskt$group)
leveneTest(mskt$fmi_total,mskt$gender)

leveneTest(mskt$ptq_total,mskt$group)
leveneTest(mskt$ptq_total,mskt$gender)

leveneTest(mskt$rrs_total,mskt$group)
leveneTest(mskt$rrs_total,mskt$gender)

leveneTest(mskt$raq_total,mskt$group)
leveneTest(mskt$raq_total,mskt$gender)

leveneTest(mskt$rep_score,mskt$group)
leveneTest(mskt$rep_score,mskt$gender)

leveneTest(mskt$int_score,mskt$group)
leveneTest(mskt$int_score,mskt$gender)

leveneTest(mskt$diseng_score,mskt$group)
leveneTest(mskt$diseng_score,mskt$gender)

leveneTest(mskt$CF_score,mskt$group)
leveneTest(mskt$CF_score,mskt$gender)

leveneTest(mskt$UP_score,mskt$group)
leveneTest(mskt$UP_score,mskt$gender)
```

```
leveneTest(mskt$MC_score,mskt$group)
leveneTest(mskt$MC_score,mskt$gender)

leveneTest(mskt$r_score,mskt$group)
leveneTest(mskt$r_score,mskt$gender)

leveneTest(mskt$b_score,mskt$group)
leveneTest(mskt$b_score,mskt$gender)

#CREATING SUBSETS FOR DEMOGRAPHICS FROM MSKT
demographics<-subset(mskt[,c(1:10)])

yoga_demographics<-subset(demographics,demographics$group=="1")
yoga_demographics<-subset(yoga_demographics[,c(3:10)])

control_demographics<-subset(demographics,demographics$group=="2")
control_demographics<-subset(control_demographics[,c(3:10)])

male_demographics<-subset(demographics,demographics$gender=="1")
male_demographics<-subset(male_demographics[,c(1,3,5:10)])

female_demographics<-subset(demographics,demographics$gender=="2")
female_demographics<-subset(female_demographics[,c(1,3,5:10)])

#CORRELATION MATRIX FOR DEMOGRPHICS FOR EACH GROUP
apa.cor.table(yoga_demographics)
apa.cor.table(control_demographics)
apa.cor.table(male_demographics)
apa.cor.table(female_demographics)
```

```
#CORRELATION ANALYSIS BETWEEN MAIN VARIABLES

#CREATING A SUBSET OF MAIN SCORES IN EACH GROUP
ymain<-subset(y[,c(25,41:47,70:72,78)])
cmain<-subset(c[,c(25,41:47,70:72,78)])
mmain<-subset(m[,c(25,41:47,70:72,78)])
fmain<-subset(f[,c(25,41:47,70:72,78)])

#CREATING CORRELATION PLOTS FOR MAIN SCORES IN EACH GROUP
corrplot(cor(ymain),type = "upper", order = "hclust",
        tl.col = "black", tl.srt = 45)

corrplot(cor(cmain),type = "upper", order = "hclust",
        tl.col = "black", tl.srt = 45)

corrplot(cor(mmain),type = "upper", order = "hclust",
        tl.col = "black", tl.srt = 45)

corrplot(cor(fmain),type = "upper", order = "hclust",
        tl.col = "black", tl.srt = 45)

#CORRELATION MATRIX FOR MAIN SCORES IN EACH GROUP
apa.cor.table(ymain)
apa.cor.table(cmain)
apa.cor.table(mmain)
apa.cor.table(fmain)

#CORRELATION MATRIX WITH SIGNIFICANCE LEVELS FOR MAIN SCORES IN
EACH GROUP
ymat<-cor(ymain)
```

```
y_ana<-rcorr(as.matrix(ymat))
y_ana

cmat<-cor(cmain)
c_ana<-rcorr(as.matrix(cmat))
c_ana

mmat<-cor(mmain)
m_ana<-rcorr(as.matrix(mmat))
m_ana

fmat<-cor(fmain)
f_ana<-rcorr(as.matrix(fmat))
f_ana

mat<-cor(main)
ana<-rcorr(as.matrix(mat))



corrplot(mat, type = "upper", order = "hclust",
         tl.col = "black", tl.srt = 45)

apa.cor.table(main)

corrplot(cor(ymain),type = "upper", order = "hclust",
         tl.col = "black", tl.srt = 45)

corrplot(cor(cmain),type = "upper", order = "hclust",
         tl.col = "black", tl.srt = 45)
```

```
corrplot(cor(mmain),type = "upper", order = "hclust",
         tl.col = "black", tl.srt = 45)

corrplot(cor(fmain),type = "upper", order = "hclust",
         tl.col = "black", tl.srt = 45)



cor_ymain<-apa.cor.table(ymain)
cor_cmain<-apa.cor.table(cmain)
cor_mmain<-apa.cor.table(mmain)
cor_fmain<-apa.cor.table(fmain)
view(mat)

#INDEPENDENT SAMPLE T-TEST FOR GROUP WISE ANALYSIS
t.test(y$fmi_total,c$fmi_total, var.equal = FALSE)
t.test(m$fmi_total,f$fmi_total, var.equal = TRUE)

t.test(y$rep_score,c$rep_score, var.equal = FALSE)
t.test(m$rep_score,f$rep_score, var.equal = FALSE)

t.test(y$int_score,c$int_score,var.equal = TRUE)
t.test(m$int_score,f$int_score,var.equal = TRUE)

t.test(y$diseng_score,c$diseng_score,var.equal = TRUE)
t.test(m$diseng_score,f$diseng_score,var.equal = TRUE)

t.test(y$CF_score,c$CF_score,var.equal = TRUE)
t.test(m$CF_score,f$CF_score,var.equal = TRUE)

t.test(y$UP_score,c$UP_score,var.equal = TRUE)
```

```
t.test(m$UP_score,f$UP_score,var.equal = TRUE)

t.test(y$MC_score,c$MC_score,var.equal = TRUE)
t.test(m$MC_score,f$MC_score,var.equal = TRUE)

t.test(y$ptq_total,c$ptq_total,var.equal = TRUE)
t.test(m$ptq_total,f$ptq_total,var.equal = TRUE)

t.test(y$r_score,c$r_score,var.equal = TRUE)
t.test(m$r_score,f$r_score,var.equal = TRUE)

t.test(y$b_score,c$b_score,var.equal = TRUE)
t.test(m$b_score,f$b_score,var.equal = TRUE)

t.test(y$rrs_total,c$rrs_total,var.equal = TRUE)
t.test(m$rrs_total,f$rrs_total,var.equal = TRUE)

t.test(y$raq_total,c$raq_total,var.equal = TRUE)
t.test(m$raq_total,f$raq_total,var.equal = TRUE)

apa()

tab1<-cor_ymain[["table.body"]]
tab2<-cor_cmain[["table.body"]]
tab3<-cor_mmain[["table.body"]]
tab4<-cor_fmain[["table.body"]]
```

10.9. APPENDIX I - CODES FOR EEGrunt

#FOLLOW DOWNLOAD INSTRUCTIONS FOR EEGrunt FROM GITHUB.

#ENSURE THAT ANACONDA LATEST VERSION IS INSTALLED

#COPY EEGrunt.py AND analyze_data.py TO THIS LOCATION - /anaconda3/lib/python3.7/site-packages/EEGrunt-master (This location is for MACOS, FIND SIMILAR LOCATION IF USING WINDOWS)

#LAUNCH ANACONDA 3

#LAUNCH SPYDER

#OPEN BOTH PACKAGES FROM SPECIFIED DIRECTORY

#ENSURE THAT THE SAME DIRECTORY IS ACCESSED IN THE TOP ROW OF THE WINDOW OR ELSE THE CODE WILL SHOW AN ERROR

#CODE FOR EEGrunt.py WITH CERTAIN VARIABLES ADJUSTED FOR THIS STUDY

```
#!/usr/bin/env python
# -*- coding: utf-8 -*-

import matplotlib.pyplot as plt
import numpy as np
import matplotlib.mlab as mlab
from scipy import signal
import sys

class EEGrunt:
    def __init__(self, path, filename, source, title = ""):

        self.path = path
        self.filename = filename
        self.source = source
        if(title):
            self.session_title = title
        else:
```

```
    self.session_title = source.title()+" data loaded from "+filename


if self.source == 'muse' or self.source == 'muse-lsl':
    self.fs_Hz = 220.0
    self.nchannels = 4
    self.channels = [1,2,3,4]
    self.col_offset = -1

else: # If it isn't Muse data, it's OpenBCI data.

    self.col_offset = 0
    if self.source == 'openbci-ganglion' or self.source == 'openbci-ganglion-openvibe':
        self.fs_Hz = 200.0
        self.nchannels = 4
        self.channels = [1,2,3,4]
    else:
        self.fs_Hz = 125.0
        self.nchannels = 16
        self.channels = [1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16]

self.NFFT = 256

self.sample_block = 11

self.plot = 'save'

self.overlap  = self.NFFT - int(0.25 * self.fs_Hz)

self.ecg_threshold_factor = 6
```

```
    self.hrv_window_length = 10

def load_data(self):

    path = self.path
    filename = self.filename
    source = self.source

    print("Loading EEG data: "+path+filename)

    try:
        with open(path+filename) as file:
            pass
    except IOError:
        print('EEG data file not found.')
        exit()

    if source == 'muse':
        skiprows = 0
        raw_data = []
        with open(path + filename, 'rb') as csvfile:
            for row in csvfile:
                cols = row.split(',')
                if(cols[1].strip() == "/muse/eeg"):
                    raw_data.append(cols[2:6])

        dt = np.dtype('Float64')
        raw_data = np.array(raw_data, dtype=dt)

    else:
```

```
        if source == 'openbci' or source == 'openbci-openvibe':
            skiprows = 6
            cols = (0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16)

        if source == 'openbci-ganglion' or source =='openbci-ganglion-openvibe':
            skiprows = 6
            cols = (0,1,2,3,4)

        if source == 'openbci-openvibe' or source == 'openbci-ganglion-openvibe':
            skiprows = 1

        if source == 'muse-lsl':
            skiprows = 1
            cols = (0,1,2,3,4)

        raw_data = np.loadtxt(path + filename,
                    delimiter=',',
                    skiprows=skiprows,
                    usecols=cols
                    )

    self.raw_data = raw_data

    self.t_sec = np.arange(len(self.raw_data[:, 0])) /self.fs_Hz

    print("Session length (seconds): "+str(len(self.t_sec)/self.fs_Hz))
    print("t_sec last: "+str(self.t_sec[:-1]))
def load_channel(self,channel):
    print("Loading channel: "+str(channel))
    channel_data = self.raw_data[:,(channel+self.col_offset)]
```

```
    self.channel = channel
    self.data = channel_data

def trim_data(self, start, end):
    # Trim data off the beginning and end to get rid of unwanted
    # artifacts (such as from applying and removing electrodes).
    #
    # Arguments 'start' and 'end' are how many seconds to trim
    # from the start and end of the data.
    #
    # Note: this must be applied to a single channel,
    # not to data that has multiple channels. For best results, run it
    # after EEG.notch_mains_interference().

    trim_start_samples = int(start * self.fs_Hz)
    trim_end_samples = int(end * self.fs_Hz)*-1

    if(trim_end_samples == 0):
        trim_end_samples = len(self.data)

    self.data = self.data[trim_start_samples:trim_end_samples]
    self.t_sec = self.t_sec[trim_start_samples:trim_end_samples]

def packet_check(self):
    data_indices = self.data[:, 0]
    d_indices = data_indices[2:]-data_indices[1:-1]
    n_jump = np.count_nonzero((d_indices != 1) & (d_indices != -255))
    print("Packet counter discontinuities: " + str(n_jump))
    self.n_jump  = n_jump
def remove_dc_offset(self):
```

```
        hp_cutoff_Hz = 1.0

        print("Highpass filtering at: " + str(hp_cutoff_Hz) + " Hz")

        b, a = signal.butter(2, hp_cutoff_Hz/(self.fs_Hz / 2.0), 'highpass')
        self.data = signal.lfilter(b, a, self.data, 0)


    def notch_mains_interference(self):
        notch_freq_Hz = np.array([50.0])  # main + harmonic frequencies
        for freq_Hz in np.nditer(notch_freq_Hz):  # loop over each target freq
            bp_stop_Hz = freq_Hz + 3.0*np.array([-1, 1])  # set the stop band
            b, a = signal.butter(3, bp_stop_Hz/(self.fs_Hz / 2.0), 'bandstop')
            self.data = signal.lfilter(b, a, self.data, 0)
            print("Notch filter removing: " + str(bp_stop_Hz[0]) + "-" + str(bp_stop_Hz[1]) + "
Hz")


    def bandpass(self,start,stop):
        bp_Hz = np.zeros(0)
        bp_Hz = np.array([start,stop])
        b, a = signal.butter(3, bp_Hz/(self.fs_Hz / 2.0),'bandpass')
        print("Bandpass filtering to: " + str(bp_Hz[0]) + "-" + str(bp_Hz[1]) + " Hz")
        return signal.lfilter(b, a, self.data, 0)


    # Convenient smoothing function from SciPy cookbook: http://scipy-
cookbook.readthedocs.io/items/SignalSmooth.html
    def smooth(self,x,window_len=11,window='hanning'):
        if x.ndim != 1:
            raise ValueError("Smooth only accepts 1 dimension arrays.")
        if x.size < window_len:
            raise ValueError("Input vector needs to be bigger than window size.")
```

```
        if window_len<3:
            return x
        if not window in ['flat', 'hanning', 'hamming', 'bartlett', 'blackman']:
            raise ValueError("Invalid window type in smooth(). Must be one of 'flat', 'hanning', 'hamming', 'bartlett', or 'blackman'")
        s=np.r_[x[window_len-1:0:-1],x,x[-1:-window_len:-1]]
        if window == 'flat': #moving average
            w=np.ones(window_len,'d')
        else:
            w=eval('np.'+window+'(window_len)')
        y=np.convolve(w/w.sum(),s,mode='valid')
        return y

    def plotit(self, plt, filename=""):
        if self.plot == 'show':
            plt.draw()
        if self.plot == 'save':
            plt.savefig(filename)
            plt.close()

    def showplots(self):
        if self.plot == 'show':
            print("Computation complete! Showing generated plots...")
            plt.show()

    def signalplot(self):
        print("Generating signal plot...")
        plt.figure(figsize=(10,5))
        plt.subplot(1,1,1)
        plt.plot(self.t_sec,self.data)
        plt.xlabel('Time (sec)')
```

```
        plt.ylabel('Power (uV)')
        plt.title(self.plot_title('Signal'))
        self.plotit(plt)

    def get_spectrum_data(self):
        print("Calculating spectrum data...")
        self.spec_PSDperHz, self.spec_freqs, self.spec_t =
mlab.specgram(np.squeeze(self.data),
                                NFFT=self.NFFT,
                                window=mlab.window_hanning,
                                Fs=self.fs_Hz,
                                noverlap=self.overlap
                                ) # returns PSD power per Hz
        # convert the units of the spectral data
        self.spec_PSDperBin = self.spec_PSDperHz * self.fs_Hz / float(self.NFFT)

    def spectrogram(self):
        print("Generating spectrogram...")
        f_lim_Hz = [0, 50]   # frequency limits for plotting
        plt.figure(figsize=(10,5))
        ax = plt.subplot(1,1,1)
        plt.pcolor(self.spec_t, self.spec_freqs, 10*np.log10(self.spec_PSDperBin))  # dB re: 1
uV
        plt.clim([-25,26])
        plt.xlim(self.spec_t[0], self.spec_t[-1]+1)
        plt.ylim(f_lim_Hz)
        plt.xlabel('Time (sec)')
        plt.ylabel('Frequency (Hz)')
        plt.title(self.plot_title('Spectrogram'))
        # add annotation for FFT Parameters
        ax.text(0.025, 0.95,
```

```
            "NFFT = " + str(self.NFFT) + "\nfs = " + str(int(self.fs_Hz)) + " Hz",
            transform=ax.transAxes,
            verticalalignment='top',
            horizontalalignment='left',
            backgroundcolor='w')
        self.plotit(plt, self.plot_filename('Spectrogram'))

    def plot_title(self, title = ""):
        return 'Channel '+str(self.channel)+' '+title+'\n'+self.session_title

    def plot_filename(self,title = ""):
        fn = self.session_title+' Channel '+str(self.channel)+' '+title
        valid_chars = '-_.()
abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789'
        filename = 'plots/'+(''.join(c for c in fn if c in valid_chars)).replace(' ','_')+'.png'
        return filename


    def plot_spectrum_avg_fft(self):

        print("Generating power spectrum plot")

        spectrum_PSDperHz = np.mean(self.spec_PSDperHz,1)
        plt.figure(figsize=(10,5))
        plt.plot(self.spec_freqs, 10*np.log10(spectrum_PSDperHz))  # dB re: 1 uV
        plt.xlim((0,45))
        plt.ylim((-5,50))
        plotname = 'Channel '+str(self.channel)+' Spectrum Average FFT Plot'
        plt.xlabel('Frequency (Hz)')
        plt.ylabel('PSD per Hz (dB re: 1uV^2/Hz)')
```

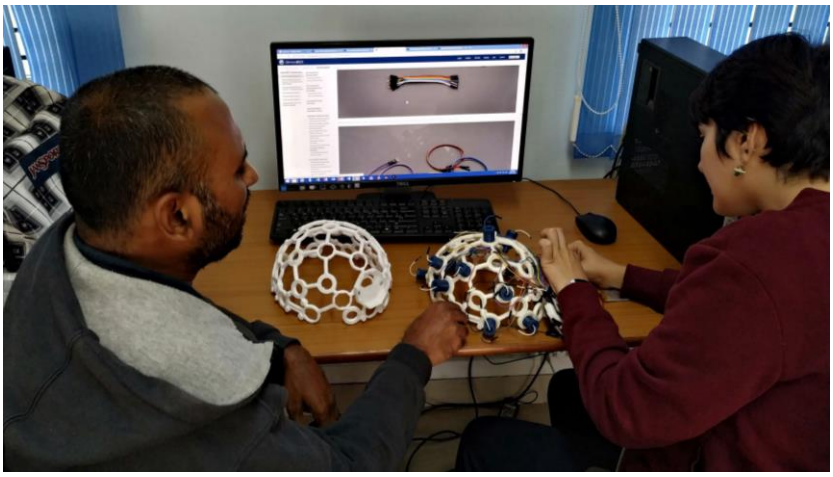
```
        plt.title(self.plot_title("Power Spectrum"))
        self.plotit(plt, self.plot_filename("Power Spectrum"))



    def plot_band_power(self,start_freq,end_freq,band_name):
        print("Plotting band power over time. Frequency range: "+str(start_freq)+" -
"+str(end_freq))
        bool_inds = (self.spec_freqs > start_freq) & (self.spec_freqs < end_freq)
        band_power = np.sqrt(np.amax(self.spec_PSDperBin[bool_inds, :], 0))
        plt.figure(figsize=(10,5))
        plt.plot(self.spec_t,band_power)
        plt.ylim([np.amin(band_power), np.amax(band_power)+1])
        # plt.xlim(len(x)/config['sample_block'])
        plt.xlabel('Time (sec)')
        plt.ylabel('EEG Amplitude (uVrms)')
        plt.title(self.plot_title('Trend Graph of '+band_name+' EEG Amplitude over Time'))
        self.plotit(plt, self.plot_filename(band_name+' EEG Amplitude Over Time'))
```

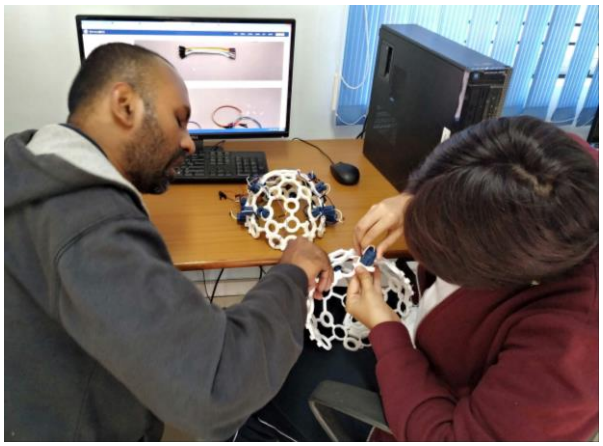
```
#CODE FOR analyze_data.py WITH CERTAIN VARIABLES ADJUSTED FOR THIS STUDY
import EEGrunt

# Required settings
# Data source. Options:
# 'muse' for data from Muse headsets.
# 'muse-lsl' for data from Muse headsets recorded with Lab Streaming Layer.
# 'openbci' for OpenBCI Cyton data recorded with the OpenBCI GUI;
# 'openbci-ganglion' for OpenBCI Ganglion data recorded with the OpenBCI GUI;
# 'openbci-openvibe' for Cyton data recorded with OpenViBE's csv writer
# 'openbci-ganglion-openvibe' for Ganglion data recorded with OpenViBE's csv writer

source = 'openbci'

# Path to EEG data file
path = '/anaconda3/lib/python3.7/site-packages/EEGrunt-master/data/'

# EEG data file name
filename = 'YR38.txt'

# Session title (used in plots and such)
session_title = "YR38"

# Initialize
EEG = EEGrunt.EEGrunt(path, filename, source, session_title)

# Here we can set some additional properties
# The 'plot' property determines whether plots are displayed or saved.
# Possible values are 'show' and 'save'
EEG.plot = 'save'
```

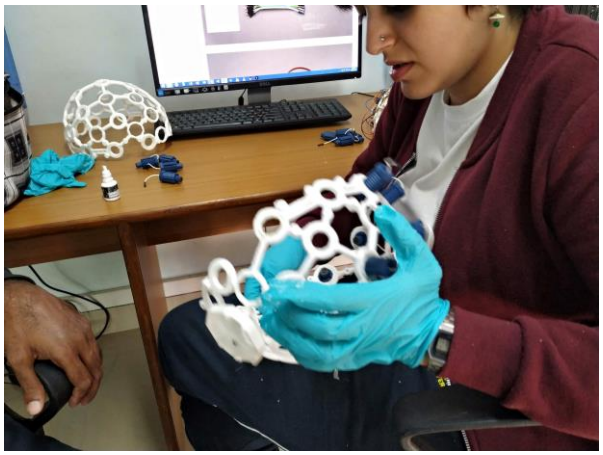
```
# Load the EEG data
EEG.load_data()

for channel in EEG.channels:

    EEG.load_channel(channel)

    print("Processing channel "+ str(EEG.channel))

    # Removes OpenBCI DC offset
    EEG.remove_dc_offset()

    # Notches 60hz noise (if you're in Europe, switch to 50Hz)
    EEG.notch_mains_interference()

    # Make signal plot
    EEG.signalplot()

    # Crunches spectrum data and stores as EEGrunt attribute(s) for reuse
    EEG.get_spectrum_data()

    # Returns bandpassed data
    # (uses scipy.signal butterworth filter)
    start_Hz = 3
    stop_Hz = 42
    EEG.data = EEG.bandpass(start_Hz,stop_Hz)

    # Make Spectrogram
    #EEG.spectrogram()
```

```
    # Line graph of amplitude over time for a given frequency range.
    # Arguments are start frequency, end frequency, and label
    #EEG.plot_band_power(4,8,"Theta")
    #EEG.plot_band_power(8,13,"Alpha")
    #EEG.plot_band_power(13,32,"Beta")
    #EEG.plot_band_power(32,42,"Gamma")

    # Power spectrum
    EEG.plot_spectrum_avg_fft()

    # Plot coherence fft (not tested recently...)
    # s1 = bandpass(seginfo["data"][:,1-1], config['band'])
    # s2 = bandpass(seginfo["data"][:,8-1], config['band'])
    # plot_coherence_fft(s1,s2,"1","8")

# When all's said and done, show the plots
EEG.showplots()
```

10.10. APPENDIX J - IMAGES








Shipley-2
Color Trails Test
TONI 4
Test of NONVERBAL Intelligence
Journal of Indian Psychology