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Seed-based Analysis of Functional Connectivity of Hippocampal Network of People Suffering from Clinical Depression

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Abstract

The absence of biological markers makes it exceptionally difficult for neurologists to diagnose a person with a mental disorder. Currently, diagnosis of mental disorders is based on behavioral observations and patient-reported symptoms and the Diagnostic and Statistical Manual of Mental Disorders (DSM) classification.

Although there have been thousands of studies revolving around implementation of various imaging modalities for deciphering the etiology and the physical cause of several mental disorders, the findings from these studies do not appear amongst the diagnostic criteria. Meaning that the findings from these studies are not used for diagnosis purposes. A critical barrier to the clinical translation of many findings is the reverse inference fallacy.

Reverse inference is a kind of reasoning that is applied to infer the involvement of a specific cognitive process from observed brain activation during a task. It attempts to uncover specific cognitive processes or behaviours that may be associated with specific structural or functional brain alterations. However, reasoning backwards from brain activity is problematic because neurological disorders are multifaceted and are influenced by several factors such as concurrent diseases, disease history and artifacts.

For this reason alone, neuroimaging is not “widely accepted” in the process of psychiatric diagnosis. Despite, the reverse inference fallacy, neuroimaging for diagnosis of mental disorders seems promising in the future and as a matter of fact, a bold (choose correct word here) minority have already started to implement neuroimaging techniques such as fMRI, SPECT, PET for the diagnosis psychiatric disorders. Nevertheless, there are no solid molecular or imaging basis that are widely accepted for the assessment of mental disorders.

Here in the proposed research we will be *assessing* MR images of 35 subjects who, are suffering or have suffered, from one major depressive disorder and *making an attempt* at arriving to a comprehensive conclusion about how the “limbic brain network” of patients suffering from Major Depressive Disorder compare to that of healthy individuals who share similar socio-demographic parameters as the subjects.

1 Introduction

1.1 Major Depressive Disorder

Major Depressive Disorder, generally abbreviated as MDD, is one of the most common and a serious mental disorder. MDD is also referred to as clinical depression, or just depression as well.

MDD can be characterized by an array of distinct symptoms; persistent feeling of sadness, feelings of low self-worth and guilt, and an overall reduced ability to take pleasure from activities that previously were enjoyable are a few symptoms prevalent in MDD. Although, the exact symptoms of depression may vary from person to person, depending on their upbringing and various socio-demographic variables such as age, sex, religious affiliations, employment, income etc; for an individual to be classified as “suffering from MDD”, five out of ten symptoms, one from a set of two and additional symptoms from another set of 5, must have to present as a bare minimum during span of 2 weeks. [reference here](#)

In addition to the symptoms that may be prevalent in a person suffering from depression, there can be morphological differences in several brain regions, including the frontal and temporal lobes. On top of that, individuals suffering from also have abnormal functional connectivity.

According to the World Health Organization, more than 264 million people of all ages suffer from depression worldwide. Fortunately, there are effective psychological and pharmacological treatments for moderate to severe depression. The pharmacological treatment includes medications, SSRIs and SNRI are two antidepressants that are most commonly prescribed. The psychological treatments include psychotherapy and electroconvulsive therapy depending on the severity of the depression, treatment can take a few weeks or much longer.

1.2 Brain Networks

A brain network, on a large scale, can be defined as a collection of brain regions working together to produce a specific function.

Brain networks can be identified at various different resolutions, therefore there is no universal atlas of brain networks that fits all circumstances. However, on the basis of converging evidences from related studies, there are six large-scale, core brain networks that are most widely accepted due to their stability:

1. Default Mode Network
2. Salience Network
3. Dorsal Attention Network
4. Frontoparietal Network
5. Sensorimotor Network
6. Visual Cortex

There are more subsets of these six networks such as the limbic, auditory, right/left executive, cerebellar, spatial attention, language, lateral visual, temporal and visual perception/imagery.

An emerging paradigm in neuroscience is that cognitive tasks are performed not by individual brain regions working in isolation but rather by brain networks consisting of several discrete brain regions that are said to be “functionally connected”. The functional connectivity of brain networks can be acknowledged through (statistical) analysis of images acquired through a variety of techniques such as the fMRI, EEG, PET or SPECT.

1.3 Resting State Functional Connectivity

Resting-state functional connectivity can be defined as a significant correlated signal between functionally connected brain regions in the absence of any stimulus or task. Resting-state functional connectivity measures **temporal correlation** of spontaneous Blood Oxygen Level Dependent (BOLD) signal among spatially distributed brain regions, with the assumption that regions with correlated activity form functional networks.

There are two methods that are most commonly used to examine functional connectivity:

- Seed-based Correlation Analysis (SCA) and
- Independent Components Analysis (ICA)

In seed-based approaches, activity is extracted from a specific region of interest and correlated with the rest of the brain. In contrast, ICA does not begin with pre-defined brain regions. It is a multivariate, data-driven approach that deconstructs fMRI time-series data throughout the brain into separate spatially independent components.

The resting state fMRI produces reliable and reproducible results, and in addition to that, there are several features of resting-state fMRI that make it favorable for investigating the correlation of psychiatric and neurological disorders. First, compared to the modular representations of traditional fMRI, functional connectivity provides a broader network representation of the functional architecture of the brain. Second, the absence of an explicit task eases the *cognitive demand of the fMRI environment*, thereby eliminating the problem of whether or not to match groups on task performance and allowing researchers to investigate under-studied populations, including infants and cognitively impaired individuals. Finally, the relatively standard manner in which resting-state fMRI data are acquired makes it ideal for multi-site investigations and data sharing.

1.4 Neuroimaging

Neuroimaging or brain imaging is the use of various techniques to either directly or indirectly image the structure, function, or pharmacology of the nervous system. Current neuroimaging techniques reveal both form and function. They reveal the brain's anatomy, including the integrity of brain structures and their interconnections. Neuroimaging falls into two broad categories:

1. Structural imaging, which deals with the structure of the nervous system and the diagnosis of gross (large scale) intracranial disease (such as a tumor) and injury.
2. Functional imaging, which is used to diagnose metabolic diseases and lesions on a finer scale (such as Alzheimer's disease) and also for neurological and cognitive psychology research and building brain-computer interfaces.

Magnetic resonance imaging (MRI) and functional magnetic resonance imaging (fMRI) scans are the form of neural imaging most directly useful to the field of psychology.

near-term and long-term prospects of neuroimaging? and what obstacles block the use of such methods?
Answer to the 2nd: The nature of imaging studies and of psychiatric diagnosis.

2 Objectives

The objectives of the proposed project are as follows:

2.1 General Objectives

- Deploy computational tools , and develop image processing strategies for the exploration of MR image datasets of brain using AFNI.
- Explore data visualization tools, with emphasis on displaying functional brain networks.
- To perform Seed-based Analysis (SCA) to explore functional connectivity within the brain based on the time series of a seed voxel or Region of Interest (ROI).

2.2 Specific Objectives

- Perform analysis of the functional and structural connectivity of the hippocampal network of patients suffering from Major Depressive Disorder and acquire a comprehensive idea about how it compares to that of normal individuals from the same socio-demographic background.

3 Problem Statement

3.1 Need For An Imaging Basis

The diagnosis procedures that are the gold standard for diagnosis of psychiatric disorders are wholly based on behavioral observations and patient reported symptoms. There are two most widely established symptoms that are used to classify these manifestations, one is the Diagnostic and Statistical Manual of Mental Disorders (DSM) and the other is International Classification for Diseases (ICD).

Despite each being as widely used as the other, both of these diagnosis manuals are more like frameworks provide a way of classifying a psychiatric disorder depending on patterns of behaviour rather than interpreting the etiology and the physical cause of those disorders.

This statement alone raises an argument that “although reliable, current diagnostic procedures in psychiatry are not entirely valid”.

Let us take an example of the diagnostic procedure involved in the diagnosis of Major Depressive Disorder. The DSM-V, published in 2013, is the most up-to-date manual and is based upon the work of expert study groups and makes use of large sets of data. According to the DSM-V, for a person to be classified as “suffering from Major Depressive Disorder”, *he/she must report with either depressed mood or anhedonia (inability to feel pleasure in normally pleasurable activities) along with four out of eight additional symptoms.*

This makes it totally possible for 2 distinct individuals who do not share a single symptom in common and yet receive treatment (or medication) for MDD.

Furthermore, the current diagnostic procedures such as the DSM-V are not perfect. For example, impulsivity, emotional lability (the property of changing rapidly), and difficulty with concentration each occurs in more than one disorder.

Now, the fact that, different exemplars of the same category can share no symptoms and that the exemplars of two different categories may share common symptoms, raises questions about the validity of the current diagnostic procedures in psychiatry.

In addition to that, some other medical conditions such as thyroid disease, brain tumors, vitamin deficiency can mimic depression like symptoms. Therefore, a may also have to be conducted in order to rule out some other medical condition that may be causing depressive symptoms. For instance, a blood test might be done to ensure the symptoms are not due to thyroid related issues.

Taking the above mentioned arguments into consideration it is crystal clear that there is a need for an imaging basis for the diagnosis of mental disorders.

3.2 Reverse Inference Fallacy

In present day and world, a variety of imaging modalities such as ultrasonography, x-rays, computed tomography, MRI, SPECT, PET, fluoroscopy, etc are being implemented for a large number of purposes, most of them include clinical diagnosis of various diseases and the others include research. Now, while some of these imaging modalities such as MRI, SPECT and PET are indeed being used for research that involve diagnosis of psychiatric disorders, they are yet to be implemented for the actual diagnosis of mental disorders.

There exists thousands of published research studies using functional neuroimaging methods such as SPECT, PET, and fMRI that revolve around diagnosis of mental disorders. However, findings from brain imaging do not appear amongst the diagnostic criteria; aside from its use to identify potential physical injury or tumours, neuroimaging is not used in diagnostic procedure in psychiatry.

Now, at first glance it might seem quite unusual and wrong and foolish that such advanced imaging techniques are not being used for diagnosis of mental disorders especially after so many researchers have done studies on it, there is actually quite a good, and as a matter of fact, quite an important reason behind it.

The reason behind this is the reverse inference fallacy. Most psychiatric imaging studies involve subjects from only two categories- patients from a single diagnostic category and people without any psychiatric diagnosis (healthy individuals), the most that can be learned from such a study is how brain activation in those with a particular disorder differs from brain activation in those without a disorder. This raises a dilemma for the diagnosing clinician, as the question is not “does this person have disorder X or are they healthy?” but rather “does this patient have disorder X,Y,Z or are they healthy?” because the pattern of images that distinguishes patients with disorder X from healthy people may not be unique to X but shared with a other disorders.

In addition to the reverse inference fallacy, standardization is another issue which contributes to neuroimaging not yet finding a place in psychiatric practice. Standardization is relevant in the sense that protocols for imaging studies differ from study to study, particularly amongst functional imaging studies.

Findings on the patterns of activation acquired in studies of psychiatric patients depends strongly on the task being performed by the subjects and the statistical comparisons made by the researcher afterwards. Such findings are pretty much incomplete unless they include the information about what task evoked the activation in question: whether the patient was resting, processing an emotional stimuli, resisting emotional stimuli or engaged in some other task? Therefore the fact that imaging study's conclusions are relative to the tasks performed adds further complexity to the problem of consistently discriminating patterns of activation of healthy and ill subjects.

A statistical approach to image analysis makes it possible to discover, spatial and temporal patterns that correspond to performance of specific tasks and specific diagnoses. Such statistical methods have only been begun to be applied to clinical disorders but show promise for increasing the “specificity” of brain imaging markers for mental illness.

Now, in the word of technology that is advancing day in day out, the scope seems promising.

- development (more sophisticated) methods of image analysis may hold promise discerning the underlying differences among the many disorders that feature similar regional abnormalities

4 Review of Literature

Implementation of fMR-imaging techniques to research the core aspects of structural and functional brain alterations in patients suffering from MDD.

Past work seems like structural MRI and fMRI look promising for providing excellent and reliable indexes for the aid in the diagnosis and ultimately treatment of MDD

tara ahile samma figure out bhako kura haru lai chai actual practice ma lyauna sakeko chaina

5 Feasibility Study

- This project will focus in analysis of the functional and structural connectivity of the hippocampal network of patients suffering from Major Depressive Disorder.
- Although the approach of neurological study is new in Nepal, various research has been conducted worldwide, so we can use the public data/information present in internet for our project.
- There isn't many components required for the project and can be carried out in given time frame with low budget.
- The research and study can be done pretty much virtually at home, which is much more favorable during pandemic moment.
- Hence, the feasibility study to conduct this proposed project is positive and supportive.

6 Methodology

7 Cost Estimations

8 Time Frame & Proposed Work Flow

9 Conclusion

10 Bibliography & References