The Correlation Between the Activity of Resting State Networks in the Limbic System and the Self-Reported Magnitude of Emotions

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Introduction

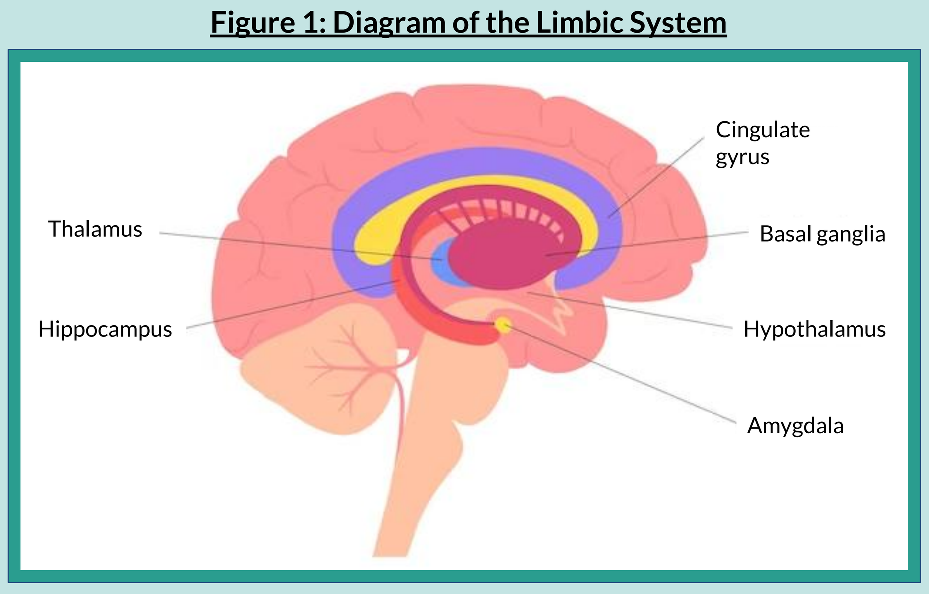
- The motivation for this study was to get a more accurate understanding of how we feel emotions by using neural activity data and psychological assessments.
  - The neural data comes from resting state functional Magnetic Resonance Imaging (**fMRI**) scans of a subject's brain.
  - The psychological assessments measured each subject's mood and emotional state. Table 1 presents an overview of the tests.

Table 1: Overview of Psychological Assessments

Assessment:	Description:
Emotion Regulation Questionnaire (ERQ)	Measures subjects' ability to regulate their emotions through cognitive reappraisal and expressive suppression. We used the reappraisal scale.
Life Orientation Test-Revised (LOT-R)	Measures the level of optimism or pessimism within the subject.
Measurement of Affect Regulation Styles (MARS)	Measures how capable a person is at managing a range of emotions. Higher scores indicate a greater ability to suppress negative emotions and thus decrease the magnitude of the emotional response. We focused only on the MARS cognitive distraction results.
Multidimensional Mood State Questionnaire (MDBF)	Measures mood on 3 scales: good-bad, awake-tired, and calm-nervous. Scores that deviate from the mean value are indicative of more extreme emotions. We used only the good-sad scale.
Toronto-Alexithymia Style (TAS)	Measures the difficulty a subject experiences when trying to understand their emotions and communicate it to others. Higher scores suggest that the subject has more difficulties. We used the overall score.

- Neural activity and psychological data were taken from the LEMON dataset, collected by Babayan et. al.
- Focused on the limbic system – **the Hippocampus, Thalamus, Amygdala, Hypothalamus, Basal Ganglia, and Cingulate Gyrus**

Figure 1: Diagram of the Limbic System



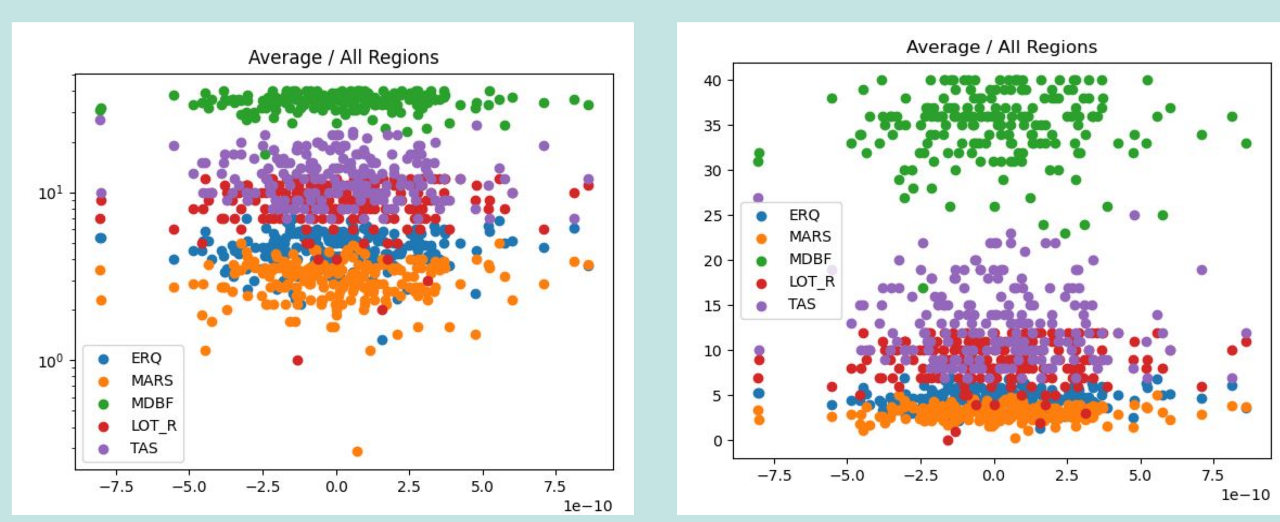
Methods

1. **Filter the data.** Using the LEMON dataset, we filtered out any unnecessary information – including subjects who did not take all of the psychological tests and any other extraneous information
2. **Compress the scans.** We were left with 202 subjects who completed all 5 necessary psychological tests and had full 10 minute fMRI resting-state brain scans. From those scans, we averaged all of the time readings, returning one single brain model for each subject.
3. **Find the relevant brain regions.** Using the Julich Brain Atlas, we isolated the areas of the limbic system and filtered out any non-limbic data
   - The Julich atlas did not have the thalamus and hypothalamus labeled. To fix this issue we used FreeSurfer, an MRI imaging software, to anatomically identify these two regions on one of our subjects.
   - After identifying the voxel space that the thalamus and hypothalamus encompassed on that subject's brain – voxel space referring to the 3D area in the scan – we used these masks to isolate the thalamus and hypothalamus in the other scans.
   - The scans were preprocessed to have their positions justified in the same digital space so the mask we created of these two regions is reasonably accurate on all of the scans.
4. **Return the neural activity data.** Using the T2 fMRI scans, which measure relative brain activity, we take the average level of activity as described by the intensity of color on the scan. This returns a single value that describes how active each brain region is, on average, during the scan.
5. **Return the scores on each psychological test.** Each subject's test scores were associated with their unique brain scan.
6. **Correlate and plot the data.** After associating each scan with the respective tests for that subject, we plotted the fMRI value on the X-axis of a plot and the scores on the Y-axis. This data visualization allows us to look for a correlation between mood, as represented by the test scores, and activity level.

Results

- We returned our data as a scatterplot with each point being an ordered pair of X: average fMRI activity and Y: psychological test score.
  - In every graph, all 202 subjects in the study have a data point for all 5 psychological tests, totalling 1010 data points per graph.
- From viewing the data, there is no immediately obvious strong correlation, however, data patterns do exist and could indicate some sort of linkage between activity and emotion

Figure 2: Plot of the average of all data. Left is on a linear scale, right is logarithmic



- It is notable that not all the regions had the same range of data. For example, the regions of the Amygdala generally were at least active at level ±1.6 whereas the Dentate Gyrus in the Hippocampus was active at level ±4.

Figure 3a: Plot of the Dentate Gyrus

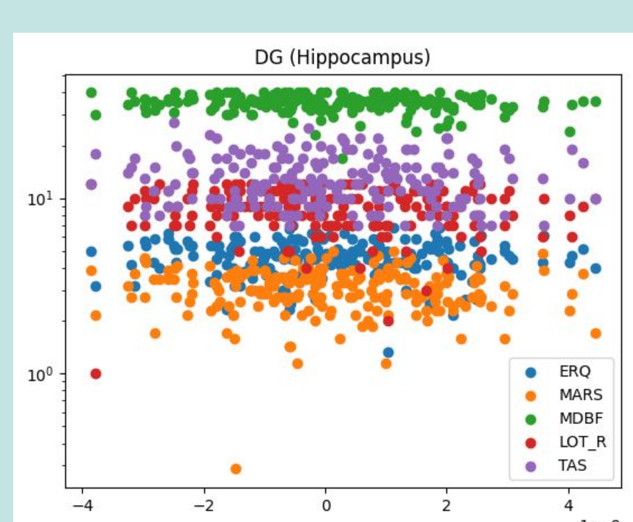


Figure 3b: Plot of the Amygdala sub-region

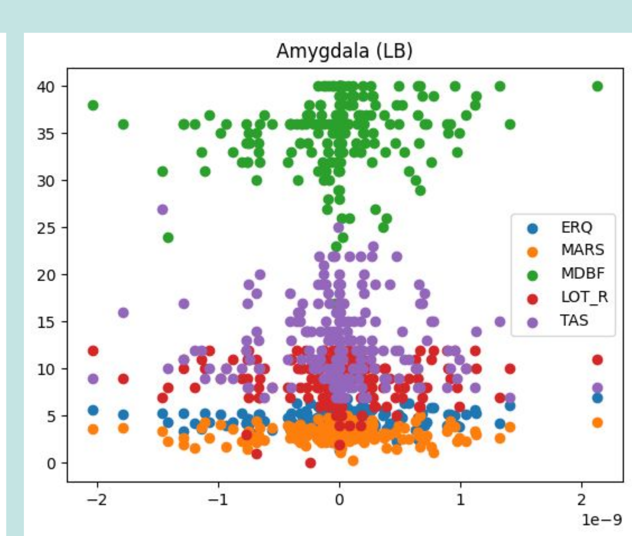


Figure 4a: Plot of the Hypothalamus

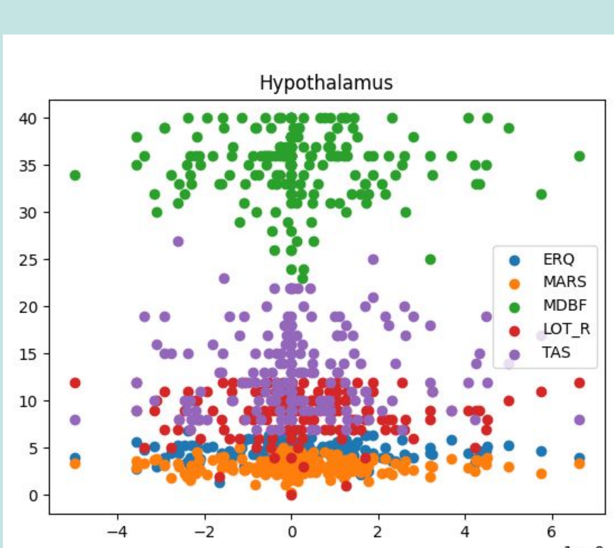
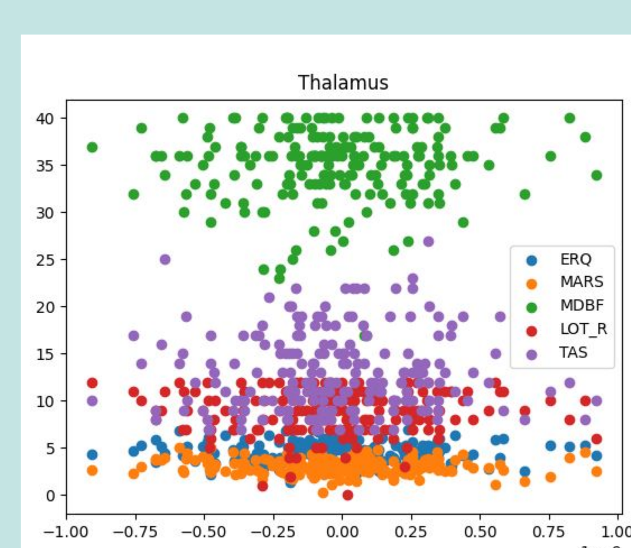


Figure 4b: Plot of the Thalamus



- Regions in which data points are clustered around zero tend to be less active during the resting state fMRI scan. This explains why the Dentate Gyrus (DG) has a high degree of variance, whereas the region in the Amygdala is clustered around zero, as the DG is more involved in resting-state functions.

Discussion

Discussion of results:

- It is important to consider the scale of the Y axis. A miniscule change in a participant's score on a test could mean different things for different tests which we are currently unable to assess.
- The lack of an immediately obvious strong correlation could be indicative of the fact that there might not be a relationship between the activity level of the limbic system and a person's emotional state. This hypothesis, however, would require further study to prove or disprove as, while this project is a start, it is unable to provide conclusive evidence to support either a correlation or lack thereof.
- **The main takeaway from this data is that, if there is a correlation between brain activity and emotion, it appears to be weak. This, if true, would tell us that abstract human emotions are difficult or impossible to derive from resting state fMRI data alone.**

Applications and future work:

- Serves as a foundation for future research or study on emotional magnitude and brain activity.
- Future studies using task-based fMRIs to measure active brain activity instead of the fMRIs used to measure resting state brain activity might be able to show a correlation that was not found in this study.

Study limitations:

1. Averaging fMRI data

Each subject's fMRI scan lasted for 10 minutes. To be able to work with this data we took an average of the level of activity throughout the entire scan. This limited the deviance of the results but also could have covered up interesting data.

2. Generalizing brain regions

Each of the brain regions we studied are subdivided into many smaller components that each have unique functions. Perhaps there is a stronger or weaker correlation within these smaller regions, however, as these smaller regions work in tandem it is likely that the results would be similar.

3. Masking of the Thalamus and Hypothalamus

As the Julich Brain Atlas did not have the coordinates for the Thalamic and Hypothalamic regions, we had to create our own masks for these regions. The brain scans were normalized, so the thalamus and hypothalamus take up the same voxel space in each image. However, there is some margin of human error here that could possibly have influenced the results as each brain is unique and these regions could be somewhat smaller or larger depending on the person.

4. Resting state

We focused on the resting state because of the constraints of available data. Given the resources to conduct our own scans, we would be able to show subjects images or videos to make them feel a certain way while they are being scanned. This would be the most accurate way to measure someone's emotional state in real time and reduce outside variables or distractions. However, because we were only able to use publicly available data, we were forced to focus on patients who were not being shown stimuli or doing tasks. Nonetheless, this data is still important because it reveals information about the functional networks in our brains.

5. Subjectivity of psychological assessments

While these psychological tests are well renowned and widely used, getting an exact understanding of someone else's feelings is near impossible and there are likely some outliers in this data. The tests cannot, unfortunately, give us a perfect representation of mood – hence the need for this study.

References

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