Statistical shape analysis of MRI: An application to the study of Schizophrenia

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Introduction

Background: Evidence of schizophrenia can be traced back to the second millennium BC; however, it was not actually called "schizophrenia" until psychiatrist Eugen Bleuler coined the term in 1911 (Pasadena Villa). Soon after this, the Diagnostic and Statistical Manual of Mental Disorders (DSM-III) outlined five different types of schizophrenia: residual, paranoid, disorganized, catatonic, and undifferentiated. They outlined these types to try to figure out the different causes and how to treat them. With this previous research, there is now a better understanding of schizophrenia and treatments for the disorder(Pasadena Villa).

Analysis: Our team researched how schizophrenia looks in the brain using magnetic resonance images (MRI) by comparing the brain scans of 14 control volunteers and 14 schizophrenia patients. We want to see if there is a difference in the shape and structure of the brain between the control patients and schizophrenic to see if there is a specific cause for this disorder. Our main focus is to understand the brain structure and to discover any differences between the two groups. The analysis uses MRI to show how the brains compare. These images revealed that patients with schizophrenia tend to have reduced hippocampal and thalamic volumes, and increased volume of the globus pallidus (Schizophrenia). We were able to plot the data on a graph to show the differences in shape. We can use brain scans and compare where different parts of the brain are on the images to see if there are any difference in the shape or structure of the brain. These images help reveal the goal of the project: is there a difference in the shape and structure of the brain between schizophrenic patients and healthy people.

DataSet and Software

The 14 control volunteers and 14 schizophrenia patients come from *Statistical Shape Analysis with Applications in* R by Ian L. Dryden. Kanti V. Mardia. This data allows researchers to look at the differences in landmarks on the brain. The analysis was preformed using the software R and its package *shapes*. All data is made publicly and available upon request.

Multidimensional Scaling (MDS)

Multidimensional Scaling is a visual representation of the relative positions of objects that are only given the distances between them. This can be found based on the Euclidean distance matrix over the number of configurations, generating the equation

$$(W)_{(h1,h2)} = \frac{1}{n}\sum_{i=1}^{n} d_i^2(h_1, h_2)$$

The equation to find the MDS based on size and shape is

$$u_{MDS} = MDS_m(W).$$

Procrustes Analysis

To test if there are differences in the mean of the shapes of brain landmarks in the two groups of schizophrenia patients, the procrustes rotation are created. There are *k* shapes and *m* dimensions. If there are two configuration matrices from k points in m dimensions X1 and X2 with pre-shapes Z1 and Z2, the closest Euclidean distance between Z1 and Z2 can be found by minimizing the distances. The full Procrustes distance is

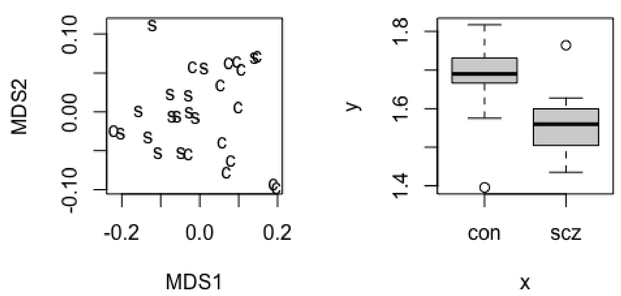
$$d_F(X_1, X_2) = \left\{1 - (\sum_{i=1}^{m} \lambda_i)^2\right\}^{\frac{1}{2}}$$

The Procrustes distances are types of extrinsic distances since they are distances in an embedding of shape space. The sum of squared full Procrustes distances from each configuration to its mean shape and the F statistic can be calculated after using the equation above.

Results and Discussion

MDS Data

Figure 1 displays the data collected from MDS data on a plot, which is a visual representation of the distances between different points on the brain to see if the size and shape differ. The left plot is a standard dot plot showing the points of the 14 control patients, "c" and the 14 schizophrenic patients, "s". There seems to be a slight difference in the people without schizophrenia compared to the people with schizophrenia. This is more clear in the box-plot shown to the right of the regular dot plot. The box-plot shows that the control patients, labeled con, have a higher centroid size compared to schizophrenic patients, labeled scz. However, this difference is not big enough to make a correlation that there is a difference in the shape and structure of the brain between healthy and schizophrenic patients.

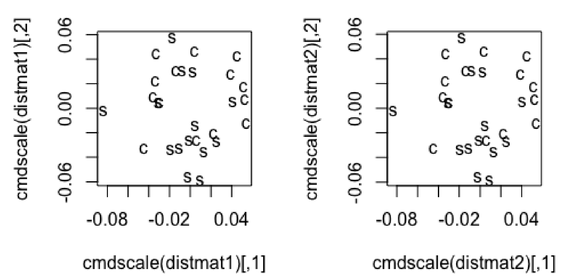


(a) MDS plot using Riemannian size-and-shape distance and (b) Boxplots of centroid size

Results and Discussion (Continued)

Procrustes Analysis Data

In Figure 2, we display the first two principal coordinates of the schizophrenia dataset. The "s" represents the schizophrenia patients, while "c" represents the control patients. The left graph uses the multidimensional scaling plot using Riemannian distance and the right graph uses full Procrustes distance. The Riemannian distance is as an intrinsic distance, since it is the shortest geodesic distance within the shape space. The full Procrustes distance is an extrinsic distance, which is shortest distances in an embedding of the shape space. Notice that there are a few schizophrenic patients that are outliers, which are observations that lie an abnormal distance from the other values. However, it is clear that the plots are extremely similar, thus the distances are similar.



MDS plots using (a) Riemannian distance and (b) full Procrustes distance

Conclusion

We studied the shape and structures variances of the magnetic resonance images between schizophrenic and healthy patients. We used two different analyses to find out the results of the study. The first was the Procrustes Analysis, and the second was the Multidimensional Scaling (MDS) analysis which are both described and evaluated in sections 2 and 3 of this paper. The results show that based on the two analyses, there are small differences in the structures of the brain between the two groups. These differences aren't extremely large, which makes us conclude that there is not a noticeable difference in the shape and structure between schizophrenic and healthy patients.