Analyzing the Development and the Functionality of Dyslexic and Autistic Brains by Investigating the Relationship between the Microstructures and Macrostructures

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1. Abstract

This work investigates the difference of the cross sectional area of the corpus callosum relative to the total brain volume between normally developed brains and individuals with autism. Our experiments consists of 39 brain volumes; 19 control cases and 20 of autistic patients. A graph cut based active contour model is used for tissue classification to segment the white matter, connected component analysis is used to extract the corpus callosum in the mid-sagittal slice. The cross sectional area of the corpus callosum, the total brain volume and the ratio between them are calculated for each case. The results show decreased ratio in autistic brains.

The poster will discuss the following aspects:
- The motivation of our work.
- The hypothesis and the justification of choosing the relative cross sectional area of the corpus callosum
- The results and the conclusion.

2. Motivation

•Does a reliable NON-INVASIVE diagnosis system for autism exist?
A combination of pathological, psychiatric and behavioral tests are used to diagnose an autistic child.

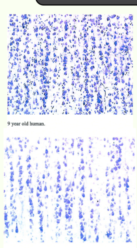
•The BIG PICTURE of our work is to find a combination of non-invasive features that can serve as an autistic signature and can uniquely characterize autistic brains.

•The OBJECTIVE of this study is to investigate one of these features: the variability of the ratio between the cross sectional area of the corpus callosum and the total brain volume among patients with autism and normal individuals.

•WHY did we choose this feature in particular?? One of the major causes of autism is that dyslexic patients suffer from malfunction of communication between the two hemispheres. Communication between the two hemispheres can be done using the intrahemispheric connections through the MINICOLUMNS or using the longer interhemispheric connections through the corpus callosum. If there is a malfunction in one of them in the autistic brain, we expect the brain to be biased to communicate the other way.

•This brings us to discuss the Pathological findings and the minicolumnar hypothesis.

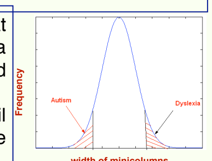
3.Neuroanatomy Background and Hypothesis



Difference between minicolumnar structures in a 9 years old and 67 years old.

The MINICOLUMN is a vertical arrangement of neurons that grows in the cortical surface. Enlargement of the cortical surface occurs through the addition of minicolumns rather than single neurons.

•Postmortem studies have shown that disturbance in the minicolumns is a common feature to both dyslexia and autism.
•Dyslexia and autism exist as opposite tail – ends within the normal distribution of the minicolumnar width.
•Larger width of minicolumns means smaller number of them and vice versa.



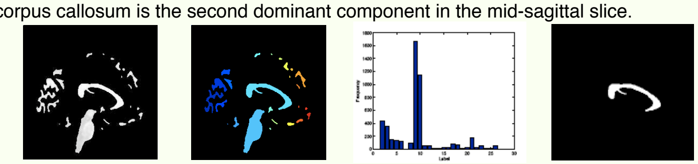
Distribution of the minicolumn width in normal, autistic and dyslexic brains

The minicolumnar interconnectivity is on the order of 1000.
- Losing one minicolumn will highly decrease the connectivity which will significantly affect the brain circuitry.
- Our hypothesis is that the dyslexic brain tries to compensate using the interhemispheric connections through the corpus callsum. On the other hand, the autistic brain will do the opposite and favor the intrahemispheric connections.

•Hence we will study the hypothesis that the CC cross sectional area is larger in Dyslexic brains and smaller in autistic brains. Since, we have earlier detected volumetric differences between normal and dyslexic brains, we will divide by the volume to obtain an unbiased estimate. Here, we will just focus on autism as we have proved the hypothesis for dyslexia in an earlier study.

4. Corpus Callosum Extraction from the Mid-Sagital Slice

The white matter in the mid-sagittal slice has two dominant components: the brain stem and the corpus callosum. We applied connected component analysis to extract the corpus callosum based on a predefined statistical model that suggests that the corpus callosum is the second dominant component in the mid-sagittal slice.


The first image shows the segmented white matter of the midsagittal slice. The second image illustrates the different connected components. The third one shows the histogram of the connected components and the last one shows the extraction of the corpus callosum as component with the second highest number of pixels.

5. Hypothesis Tests and Results

Having segmented the brain tissue and extracted the corpus callosum, the statistical analysis consists of the following steps;
1. The total brain volume (TBV) and the area of the corpus callosum surface area in the midsagittal section (CCA) for each of the autistic and normal cases were calculated.
2. The ratio R=TBV/CCA was calculated for each case. The normal group has a mean ratio μ_{RN} and standard deviation σ_{RN}, the autistic group has a mean ratio μ_{RA} and standard deviation σ_{RN}. A sample results for the ratio (scaled by 1000) is shown in the following table

case	1	2	3	4	5	6	7	8	9	Mean
Autistic	9.2855	10.7949	10.0893	12.8449	13.6817	10.0893	0.4289	9.8115	12.7099	12.1655
Normal	16.6394	14.0226	12.9970	16.6609	14.9436	10.7540	11.5691	14.4700	5.8310	13.4143

Test 2: We tested the null hypothesis $\mu_{RN} = \mu_{RA}$ versus $\mu_{RN} > \mu_{RA}$ to investigate whether a significant difference between the two groups exists or not. We used the t-distribution to perform the test. We tested the hypothesis at two significance levels 0.05.
Result: The result of the hypothesis testing suggests that the ratio of the corpus callosum area to the total brain volume in normal cases is significantly larger than its corresponding in autistic patients.

6. Conclusions

The conclusions of our study can be summarized in three main points:
Direct Result of the Analysis: The ratio of the corpus callosum cross sectional area to the total brain volume in control cases is significantly larger than its corresponding in autistic patients.
Functional Implications: Autistic brains tend to prefer intrahemispheric connections through the minicolumns in the cortex over the interhemispheric connections through the corpus callosum .
Impact: The results that we have illustrated here goes far beyond being a difference in measurements of a certain structure. The results are correlated to the pathological findings that suggest smaller minicolumns in dyslexic brains. They represent an MRI evidence that supports the minicolumnar hypothesis.

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