Synthesis of Neonate Connectomes for Artificial Sentience and Common Sense

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Michael Bihn and Rory Lewis

Dept. of Computer Science
University of Colorado at Colorado Springs
Colorado Springs, USA

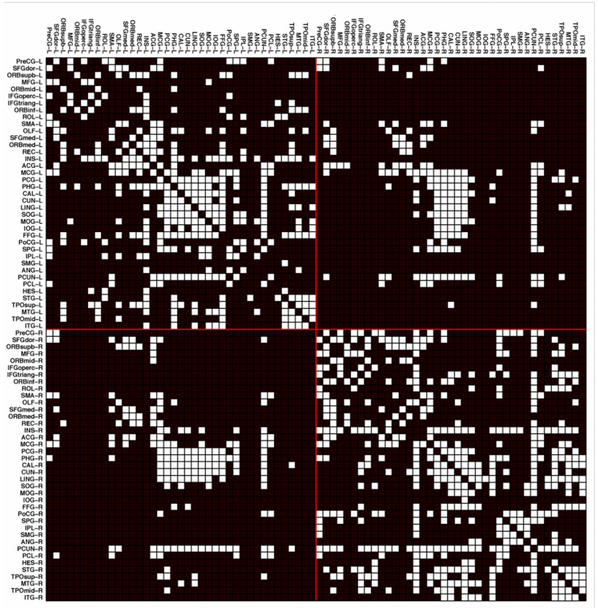
IARIA

UCCS

Neonate Connectomes & Common Sense

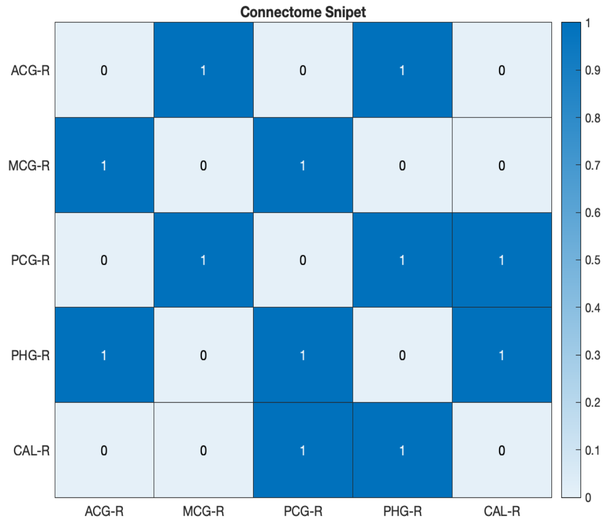
Connectomes

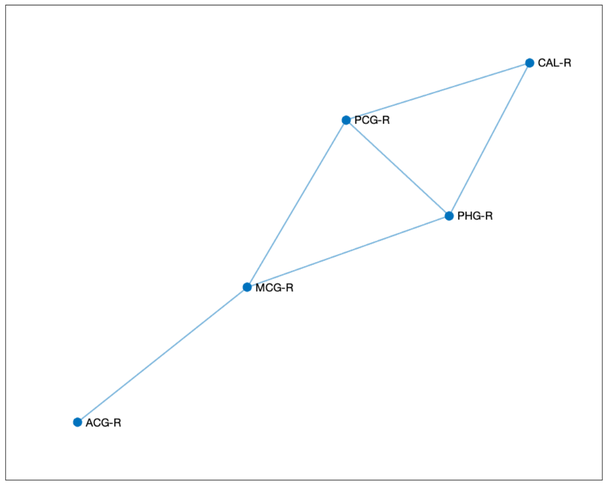
The Connectome is a matrix with rows and columns representing the 78 brain lobes and the row I column J box is white if there is a neuronal pathway between brain lobe I and brain lobe J



Connectome Snippet

Here is a snippet of the connectome and associated graph. Notice the brain lobes are graph nodes and the connections are edges.





Patterns of change over time

Binary Triplets of ones and zeroes:

first digit represents the connectivity at two-weeks-old

Second digit represents the connectivity at one-year-old

Third digit represents the connectivity at two-years-old

For the 78 cross 77 lobes of the brain, giving 3003 bidirectional connections

Pattern	Number
000	2120*
001	64
010	53
011	136

Pattern	Number
100	161
101	28
110	39
111	402

Single Shortest Path, SSP

SSP, from any brain lobe to any other brain lobe over the connectome pathways.

Define the Traversal, Ti, for a brain lobe i, to be the sum of all the SSP's for that brain lobe: $Ti = \sum_{j=1, j \neq i}^{78} SSP(i, j)$

Define the Minimum Traversal: $MinT = minimum(Ti, i = 1..78)$

Define the Maximum Traversal: $MaxT = maximum(Ti, i = 1..78)$

The changes over time

- The $MaxT$ is decreasing from 257 to 219 to 212
- The $MinT$ is increasing from 107 to 127 to 128

Optimization Problem

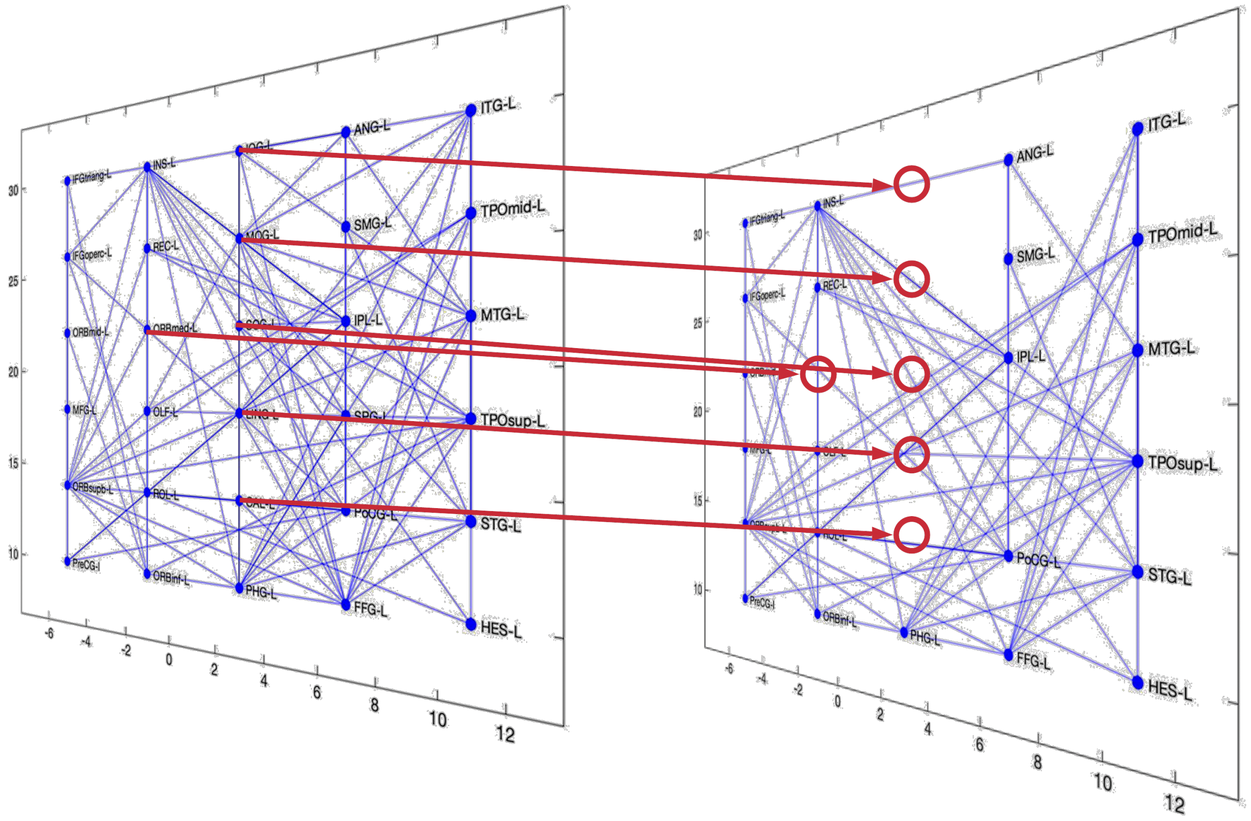
Minimize the $MaxT$ over time

The constraints:

- Maintain the constant 630 connections, therefore the changes must be implemented in pairs, one connect for every disconnect
- Maintain the full connectedness, there is always a path from any brain lobe to all the other brain lobes over the connectome. No orphan creation.
- 189 pairs of changes from two-weeks-old to one-year-old
- 92 pairs of changes from one-year-old to two-years-old
- Scripted ordering of development from DNA
- Prototype execution shows the type of changes.

What to look for in the Execution

In the graphical representation, the nodes represent the brain lobes and the edges represent the neuronal pathways. The lobes and neuronal pathways can be connected or disconnected from a module over time



Execution

Prototype execution shows the type of changes.

The changes do not change *en masse*, that would violate the constraints

Need to create a function that predicts connect/disconnect over time

The average synapse length is growing over time

Need a function for either myelination production and/or synapse length growth.

Should have the connection lengths, how else could you produce an average

Synthesize the connectome development onto a machine

Minimizing Max Traversal

The minimizing Max Traversal provides a shorter path for any brain lobe to send any signal to all the other brain lobes.

Shorter path leads to quicker brain signal transmission

“Quick wittedness” vs. “Not the sharpest tool in the shed”

Both phrases are common judgements of a person’s level of common sense.

Approach common sense from a neurological approach

Not a psychological approach

Let the Neuroscience lead us

Experiment Procedure

Preliminary data clean up of brain lobe assignment to module #’s

Examined the module # assigned to the individual 78 brain lobes

Module # represents connectivity

Corrected the numbering of the modules for the one-year and two-year connectomes

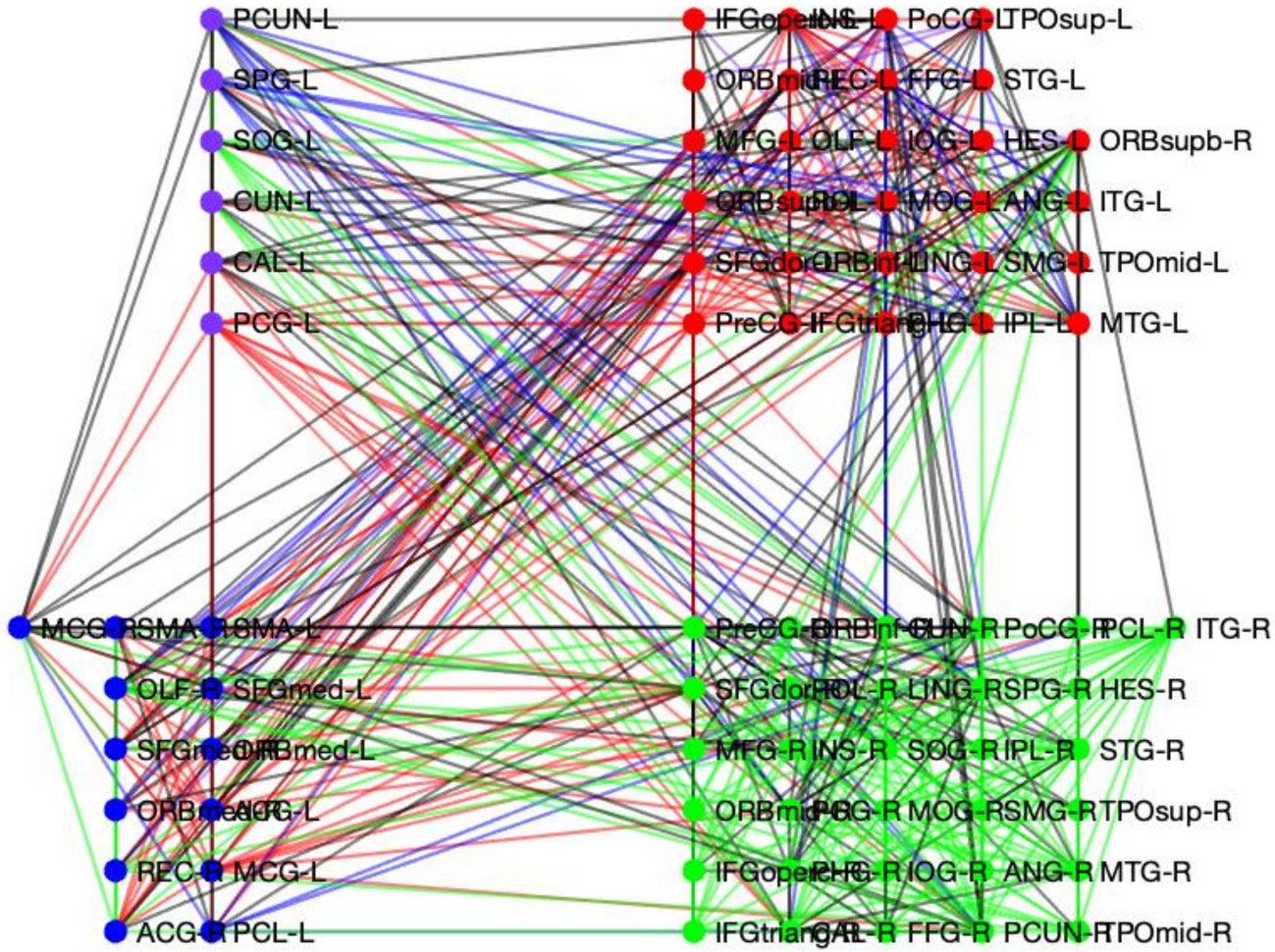
Swap module numbering 1 and 2 for one-year-old

Swap module numbering 2 and 3 for two-year-old

Net result: reduced the number of lobes that changed modules from 77 out of 78 to 17 out of 78 while maintaining connectivity

Mapping

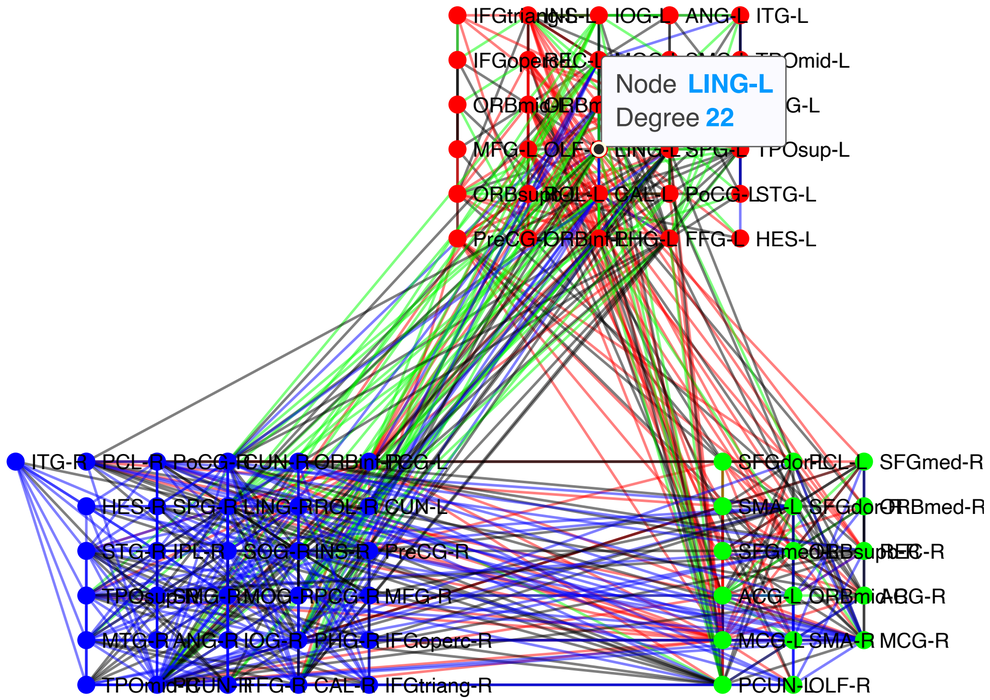
78 lobes in the four modules with 630 connections of the two-year-old graph is unreadable even with arbitrary coordinates to separate the nodes for label readability



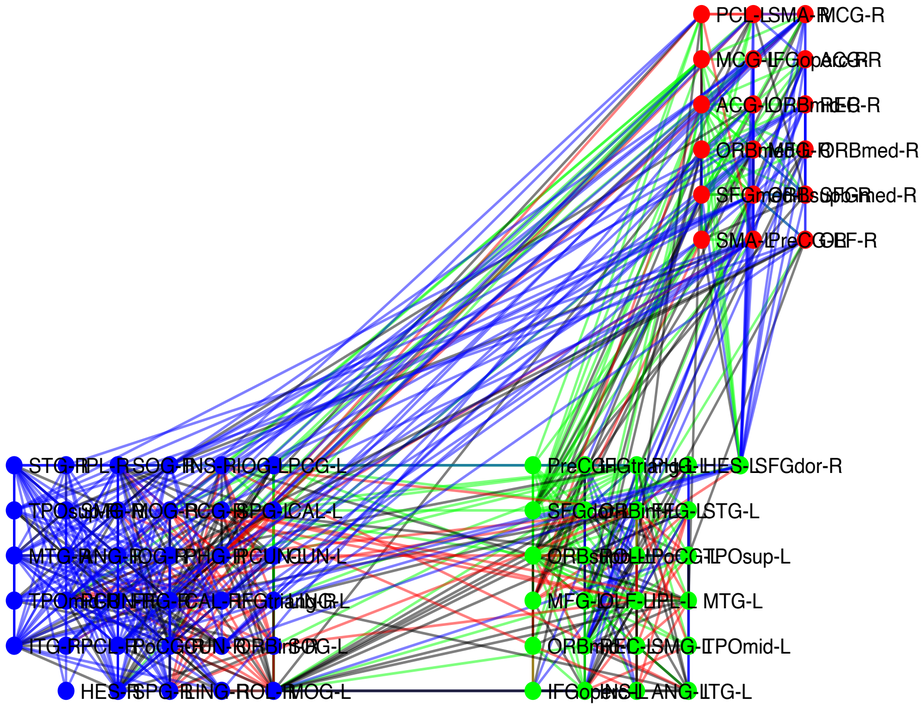
Will need 3-d coordinates and a graphical display tool for the final product. Coordinates may change over time. Lobe names will be even more obscure

Two-Week and One-Year Graphs

78 lobes in the three modules, with 630 connections in the two-week-old graph



78 lobes in the three modules, with 630 connections in the one-year-old graph



Future

Accuracy Assessment

NIH baby connectome started in 2016

Recently started collecting data in 2019

- Monthly connectomes
- Birth to five years old

Goal is to complete our synthesis before their completion

Evaluate how close our predictions

Possibly continue the effort

Conclusion

Conclusion

- Rapidly changing connectome in the first years of life
- Max Traversal shortens over time
- Always 630 connections
- Always fully connected

Future work

- Use a neuroscience approach
- Synthesize the connectome development
- Refine the synthesis as neuroscience research develops
- Study other approaches for a neuroscience implementation

Thank you