Human Connectome: Developmental Patterns and Brain Maps

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Author: *Your Faithful Brain: Designed for so much more!*
Overview

Who does this affect?
Why?
What is being done?
How can I use this to help my clients?

Questions

3-D Brain Tour
Your Brain Requires Resources

- 25% of your oxygen
- 20% of your glucose
Who?
Derek & Alice

39 y-o husband & wife
Married > Re-Married
Three sons, ages 2, 4, 5

Derek on Autism-Spectrum
Hyperactive Childhood  >>
>> Hyper-focused Adult

Divorce Threatening
Derek w Reactive Depression & Anxiety
Human Connectome Project’s Why?

- Remediate (developmental) brain disorders.
  - Dyslexias
  - Schizophrenias
  - Anxiety Disorders
  - Addictive Disorders
  - Depressive Disorders
  - Personality Disorders
  - Autism-Spectrum Disorders
  - Attention Deficit Hyperactivity Disorders

- NIH Studies of Normal Brain Development
  - Pediatric MRI Data Repository (2006)
  - Adolescent MRI Data Repository (2012)
Len’s Why?

- Intersection of faith and neuroscience helps us understand God’s design for relationship.
  - How God communicates with us.
  - How we participate with God.
  - How we relate with each other.

- And, most importantly ...
... how loving God and each other is **optimal** for brain health and fitness and quality-of-life.

“Love the Lord your God with all your heart and with all your soul and with **your entire mind**. This is the first and greatest commandment. And the second is like it: Love your neighbor as yourself.”

Matthew 22:37–39
... how loving God and each other is optimal for brain health and fitness and quality-of-life.

“Love the Lord your God with all your heart and with all your soul and with your entire mind. This is the first and greatest commandment. And the second is like it: Love your neighbor as yourself.”

Matthew 22:37–39
... how loving God and each other is necessary for brain health and fitness and quality-of-life.

“Do not conform to the pattern of this world, but be transformed by the renewing of your mind. Then you will be able to test and approve what God’s will is—his good, pleasing and perfect will.”

Romans 12:1-2
Neuron

Born with more than our mother and rapidly grow new neurons, but lose those that aren’t used.

$\approx 100$ billion neurons + $1$ trillion glial cells.

Cortex down-regulation develops into mid-20s.
“Gray Matter” in Layers and Columns

Six layers in cerebral cortex.

Each layer has a different function.

Each layer thickness of one business card!

Golgi stain of cerebral cortex
Many Linkages

Each averages 10,000 links.

Purkinje cells ≈ 200,000 links.

A link either excites or inhibits the next neuron.

Possible combinations is beyond counting:

“Godzillion”

Purkinje Cell
Ramon y Cajal 1913
Constantly Changing

Neuroplasticity ≈ 1885

Neurogenesis ≈ 1995

Neuroconsolidation ≈ 2005
Biblical Neurorehabilitation

- Bach y Rita Family ≈ 1960
- Mike Merzenich & Jon Kaas ≈ 1985
- Edward Taub ≈ 2000
  - Constraint-Induced Movement Therapy
- Francis Collins ≈ 2005
  - The Language of God
What: “Human Connectome”

- Comprehensive map of brain and nervous system neural connections.
- NIH *Blueprint for Neuroscientific Research*
  1. Washington University, St. Louis & U Minnesota
  2. Harvard / Massachusetts General Hospital & UCLA
Human Connectome Project (HCP)

- Wash U St. Louis + University of Minnesota
  1. Structural MRI to develop topographic maps
  2. Resting-state fMRI to identify default networks
  3. Task-specific fMRI to identify functional networks
  4. Diffusion imaging to map links among networks
HCP Brain Connectivity Maps

- 1,200 healthy adults
  - Monozygotic (identical) twins
  - Dyzogotic (fraternal) twins
  - Non-twin siblings
Michelangelo's Sistine Chapel Brain

circa 1500
Michelangelo's Sistine Chapel Brain
Michelangelo's Sistine Chapel Brain
Four Cortical Regions circa 1850
Phineas Gage

American railroad foreman drilling rock in 1847. Spark triggered explosion that drove tamping rod through his skull and frontal cortex.

Survived with different personality; disrespectful, profane, impulsive, and unreliable.

Frontal cortex crucial for personality and behavioral control.
1909
52 Different Cortical & Sub-Cortical “Brodmann Areas”
2007
300 Different Combinations of Nuclei and Networks

How can we make sense of this?
HCP Game Plan

1. EEG/MEG/fMRI → Time course

2. Structural MRI → Morphological metrics

3. Diffusion MRI → White matter tracts

4. Time course → Templates

5. Templates → Connectivity matrix

6. Connectivity matrix → Brain network
HCP 7-Tesla Brain MRI
Structural MRI

- High-resolution for topographic maps
- Differences in brain structure for:
  1. Schizophrenia?
  2. Bipolar?
  3. Autism?
  4. ADHD?
Which brain belongs to a person such as Derek?
Resting-State fMRI

• “Resting” brain observed through changes in blood-oxygen-level dependent (BOLD) signal.
• Patterns of synchronous activity regions are being found in healthy subjects.
• Sets a baseline to detect impairment before symptoms are evident.
HCP Resting-State fMRI
April, 2015 (n = 468)
UCSD
Resting fMRI

Toddlers with Autism

Derek’s parents were VERY lucky!
Task-Specific fMRI

• Explores how brain’s function *normally* corresponds to challenges.

• Response networks that should be there but aren’t are early warning indicators.

• Differences in brain function for:
  1. Schizophrenia?
  2. Bipolar?
  3. Autism?
  4. ADHD?
Diffusion Tensor Imaging

- Water molecules diffuse along axons.
- Colors indicate directional movement.
- Missing pathways can be identified if we know what to look for.
Red = left to right
Green = front to back
Blue = top to bottom
Electron Microscopic Neuron Fly-By
Faithful Brain Development

1. Brain-Restorative Sleep
   *Personal Prayer Relaxation*

2. Happy Hippocampus Exercise

3. Joyful Goaling

4. Just-Right Challenges

5. Serial *Counseling Progress Assessments*
Why Brain-Restorative Sleep?

- Re-establishes homeostatic rhythm to promote brain health and fitness.
- Brain must dissipate waste products, perform housekeeping, and restore energy reserves.
- Neuroconsolidation prepares the brain for creative exploration.
Neuroconsolidation?

• During sleep, information is consolidated:
  1. Thalamus blocks input from the senses.
  2. Pons paralyzes musculoskeletal system.
  3. Hippocampus converts a small portion of information into long-term memories.
  4. Cerebral cortex creates your story.

*Self-Directed Neuroconsolidation*
How Much is Brain-Restorative?

- 4 cycles is necessary for brain maintenance.
- 5 cycles is necessary for brain restoration.
- If you’ve had BRS, you will awaken:
  - Spontaneously
  - Feeling refreshed
  - Experiencing *Ah-Ha!*
  - One way the Holy Spirit communicates with us.
Derek & Alice?

Administered CPA Joint Session

Quality-of-Life quantified became a point of inflection.

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**Solutions Counseling Progress Assessment**

*Initials: DB Age: 39 Gender: Male Counselor: Len Matheson, PhD, CVE, CRC Date: 9/17/2015*

Welcome! Counseling is an effective way to address important quality-of-life issues. It’s helpful to measure your progress periodically. Thank you for completing our online questionnaire. Here are your results.

<table>
<thead>
<tr>
<th>In the past seven days ...</th>
<th>Response</th>
<th>Review</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I felt fearful.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I found it hard to focus on anything other than my anxiety.</td>
<td>Sometimes</td>
<td></td>
</tr>
<tr>
<td>3. My worries overwhelmed me.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I felt uneasy.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I felt nervous.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. I felt like I needed help for my anxiety.</td>
<td>Sometimes</td>
<td></td>
</tr>
<tr>
<td>7. I felt anxious.</td>
<td></td>
<td></td>
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<tr>
<td>8. I felt tense.</td>
<td></td>
<td></td>
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<tr>
<td>10. I felt helpless.</td>
<td></td>
<td></td>
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<tr>
<td>11. I felt depressed.</td>
<td></td>
<td></td>
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<tr>
<td>12. I felt hopeless.</td>
<td></td>
<td></td>
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<tr>
<td>13. I felt like a failure.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. I felt that I had nothing to look forward to.</td>
<td>Often</td>
<td></td>
</tr>
<tr>
<td>16. I felt that nothing could cheer me up.</td>
<td>Always</td>
<td></td>
</tr>
<tr>
<td>17. My sleep was refreshing.</td>
<td>Quite a bit</td>
<td></td>
</tr>
<tr>
<td>18. I had a problem with my sleep.</td>
<td>Very much</td>
<td></td>
</tr>
<tr>
<td>19. I had difficulty falling asleep.</td>
<td>Very much</td>
<td></td>
</tr>
<tr>
<td>20. My sleep was restless.</td>
<td>Quite a bit</td>
<td></td>
</tr>
<tr>
<td>21. I tried hard to get to sleep.</td>
<td>Somewhat</td>
<td></td>
</tr>
<tr>
<td>22. I worried about not being able to fall asleep.</td>
<td>Not at all</td>
<td></td>
</tr>
<tr>
<td>23. I was satisfied with my sleep.</td>
<td>A little bit</td>
<td></td>
</tr>
<tr>
<td>24. My sleep quality was</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>25. Taking everything into account, my quality-of-life was</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>26. I pray daily.</td>
<td>Agree</td>
<td></td>
</tr>
<tr>
<td>27. I look to my faith to provide meaning and purpose in my life.</td>
<td>Agree</td>
<td></td>
</tr>
<tr>
<td>28. I consider myself active in my faith or church.</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>29. I enjoy being around others who share my faith.</td>
<td>Disagree</td>
<td></td>
</tr>
<tr>
<td>30. My faith impacts many of my decisions.</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>31. The faith or religious tradition I identify with</td>
<td>Christian</td>
<td></td>
</tr>
</tbody>
</table>

**Taking everything into account, my life is ...**

<table>
<thead>
<tr>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
<th>5.5</th>
<th>6</th>
<th>6.5</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very distressing; it is hard to imagine how it could get much worse.</td>
<td>Great; it is hard to imagine how it could get much better.</td>
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Follow-Up Opportunities

• BRS & PPR at Wash U Annual Concussion Research Conference - **October 17, 2015**
• CPA **free** from Faithful Brain Research Foundation
  ▫ **Mark@faithfulbrain.com**
• HCP Data and Software **free**
• Volunteer for an Institutional Review Board **free**
• Follow Len’s Faithfulbrain.com blog **free**