Emerging Brain Imaging Methods for Assessing Normal and Abnormal Cognitive Function

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BRAIN IMAGING

STRUCTURAL

MRI

FUNCTIONAL

PET

fMRI
Magnetic Resonance Imaging
Susceptibility Weighted Imaging

T2

SWI
Diffusion Weighted Imaging
Håberg et al., *Journal of Neuroscience Research*, 2014
BRAIN IMAGING

STRUCTURAL

MRI

PET

FUNCTIONAL

fMRI
Functional MRI
Functional Brain Connections
The brain is organized into “modules” (or communities)

- Central module
- Parieto–frontal module
- Medial occipital module
- Lateral occipital module
- Fronto–temporal module
The brain is a modular system

- Modules are a set of independent and self-contained units that can be used to construct a more complex structure
- Each module comprises a number of nodes that are densely intra-connected to each other but sparsely inter-connected to nodes in other modules
- Modules implement discrete functions
- Modules interact with each other through "connector" hubs
Impact of nodal role on modularity

Module 1
- Milwaukee

Module 2
- Chicago
- San Francisco
- New York

Module 3

HUB
CONNECTOR
Effect of focal lesions on brain modularity
Warren et al., *PNAS*, 2014

**Domains**
- Orientation
- Perception
- Memory
- Verbal Func.
- Construct.
- Concept Form.
- Exec. Func.
- Personal Adj.
- Adaptive Func.

**Control Group**
- amPFC
- pCC

**Target Group**
- L pMFG
- L alns
- dmPFC
- R alns
- R pMFG
- L pMTG

**Impairment rating**
- 0
- 1
- 2

**CONNECTOR**
- **HUB**
<table>
<thead>
<tr>
<th>Disorder</th>
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<tbody>
<tr>
<td>Attention deficit hyperactivity disorder</td>
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<tr>
<td>Amyotrophic lateral sclerosis</td>
</tr>
<tr>
<td>Anorexia nervosa</td>
</tr>
<tr>
<td>Asperger’s syndrome</td>
</tr>
<tr>
<td>Autism (pervasive developmental disorder excluding Asperger’s syndrome)</td>
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<tr>
<td>Bipolar affective disorder</td>
</tr>
<tr>
<td>Chronic pain</td>
</tr>
<tr>
<td>Dementia in Alzheimer’s disease</td>
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<tr>
<td>Dementia in Parkinson’s disease</td>
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<tr>
<td>Depressive disorder</td>
</tr>
<tr>
<td>Developmental dyslexia</td>
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<tr>
<td>Dystonia</td>
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<tr>
<td>Frontotemporal dementia</td>
</tr>
<tr>
<td>Hereditary ataxia</td>
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<tr>
<td>Huntington’s disease</td>
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<tr>
<td>Juvenile myoclonic epilepsy</td>
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<tr>
<td>Multiple sclerosis</td>
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<tr>
<td>Obsessive-compulsive disorder</td>
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<tr>
<td>Obstructive sleep apnoea</td>
</tr>
<tr>
<td>Panic disorder</td>
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<tr>
<td>Parkinson’s disease</td>
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<tr>
<td>Progressive supranuclear palsy</td>
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<tr>
<td>Post traumatic stress disorder</td>
</tr>
<tr>
<td>Schizophrenia</td>
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<tr>
<td>Temporal lobe epilepsy – left</td>
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<tr>
<td>Temporal lobe epilepsy – right</td>
</tr>
</tbody>
</table>

>20,000 patients
26 brain disorders

Crossley et al., *Brain*, 2014
Individual differences in brain modularity

Low Modularity

High Modularity

Subject 1

Subject 2
Brain modularity and behavior

![Graph showing the relationship between TRAIT (Modularity) and WM Capacity with r = 0.56, including data points for Session 1 and 2, and Session 1 only.]

**Trait**

**State**

- Easy
- Medium
- Hard
Baseline brain modularity predicts hits and misses

Sadaghiani, Poline, Kleinschmidt, D’Esposito, PNAS, 2015
Cognitive therapy intervention for traumatic brain injury

Pre-assessment

Goal Management Training or Brain Health Education

Post-assessment

Follow-up assessment

- Wk 1
- Wk 3
- Wk 8
- Wk 10
- Wk 26

- 10 Sessions (2x / week) = 20 hours
- 20 hours @ home
- 3 hours one-on-one training
- Individual and group projects

- Neurocognitive Assessment
- Functional Assessments & Questionnaires
- Functional Imaging (fMRI)
Baseline modularity predicts cognitive training effects

Traumatic Brain Injury

Baseline Modularity

Arenmann et al., *Neurology*, 2015
Baseline brain modularity predicts cognitive training effects

Traumatic Brain Injury
Goal-Management Training

Healthy Young
WM Video Game Training

Healthy Older
SMART Training

Baseline Modularity
Duncan & Small, *Brain Connectivity*, 2017