Complex Musical Brain Networks:
Six Degrees of Mozart and the Beatles

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• Talk about reductionism

• Not the elements themselves, but the interaction between the elements
Facebooking the Musical Brain
Social Networks

The Road to 200 Million

Facebook began as a private network for colleges and universities, but has grown into an international social networking site with almost 200 million members. Lee Byron, a member of Facebook’s data team, created maps.

UPDATE: August, 2010

More than 500 million Facebook users

Facebook begins at Harvard, and expands to a few universities at a time.

Facebook expands to include most American colleges and high schools.

Facebook opens registration to allow anyone to join, which brings in older members.

Facebook reaches 50 million users, with Canada and Britain growing fastest.

Facebook is translated into more than 40 languages. The fastest-growing group of members is people over 35.
Modeling with networks
Network Theory
Online Music Listening

http://sixdegrees.hu/last.fm
US Power Grid
Networks

http://www.aaronkoblin.com/
High School Sexual Network

Moody et al, AJS vol 110, 2004
Human Brain Functional Network

Hayasaka, 2009
Graph Theory

- Graph: representation of relationships by
  - Nodes corresponding to each unit
  - Edges connecting nodes
Small-World Phenomenon

- Q: How connected are two complete strangers?
- A: About six steps

Milgram’s small-world experiment (1967)

Stanley Milgram

Hayasaka & Laurienti, HBM2009
6 Degrees of...
Network Metrics

**clustering coefficient (C) REGIONAL SPECIFICITY**
Probability of your friends also being friends with each other

**path length (L) DISTRIBUTIVE PROPERTIES**
Average shortest distance between any two nodes
**Degree**

- **Degree – K**
  - Number of connections for each node
  - The distribution is assessed to evaluate network type
What is a hub?

Chen and Sharp. Bioinformatics 2004, 5:147
Small World

Lattice

Small-world

Random
Vulnerability

www.geology.com

www.nyc.metablogs.com
Human Brain Functional Network

Hayasaka, 2009
Extracting Network from fMRI
The Human Brain Network Model

Correlation Matrix

1 15000
15000
Connections of the Human Brain Network

Adjacency Matrix

15000
The Human Brain Functional Network

- Functional Brain Network
- Network Metrics
- Image Maps
## Small-world Parameters

<table>
<thead>
<tr>
<th>Global Properties</th>
<th>Cluster Coefficient</th>
<th>Path Length</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Brain</strong></td>
<td>0.24</td>
<td>4.86</td>
</tr>
</tbody>
</table>
Network Parameter Maps

Small-world parameters

Degree maps
State-Based Network Changes

Young

Older

Rest

Degree

0.06 0.33 0.66

Clustering
Regional Clustering: Multisensory

Young

Old
Anterior Cingulate Cortex: Clustering

Young

Old

% of Subjects

20

80
Society for Clinical Neuromusicology

Focusing on the Applied Neurosciences of Music

The First World Congress of Clinical Neuromusicology
Effects of Music (EOM) on the Brain

• State-based phenomenon
  – Perfect for Network Approach
• Many possible questions
  – Genre specific?
  – What brain connection to favorite music?
  – What is going on when dislike music?

  – How do certain therapies alter our musical experience?
Experimental Setup

• Recruitment: genre-based
• Battery of questions
• fMRI Paradigms
fMRI Paradigms

• Favorite Song: person-specific

• All get the following
  – Classical: Beethoven’s 5th Symphony
  – Rap/Hip-Hop:
  – Rock:
  – Country:
  – Chinese Opera:
Musical Network Maps
Brain Perfusion Older Adults

Young

Older

Default-Mode Network

ml/100 gm tissue/min

T score

3

5
Default-Mode Network

Degree

T score
Implications of Small-Worlds

- “Local and global” processing
- Ubiquitous among self-organized systems
- Promote synchrony
- Model and predict behavior of networks
The Brain as a Network

- Brain network is small world
  - Structure
  - Function
- Small-world properties altered
  - Epilepsy
  - Schizophrenia
  - Aging and AD
- Connectivity exhibits hubs
- Hubs change with
  - State
  - Disease

What do we want to measure?

www.public.asu.edu/~wtvyler/lab/Optogenetics.html
State-Based Network Changes

Young

Older

Rest

Degree

Clustering

0.06 0.33 0.66