Social interaction in the typical and autistic brain

Antonia Hamilton
University of Nottingham ➔ UCL

Everything is social

- Asch conformity experiments

Why be social?

- To predict others
- To influence others

Bryne, 1989 – Machiavellian Intelligence Hypothesis
Humans evolved big intelligent brains in order to be better at social cognition

Niccolo Machiavelli

Types of social cognition

- Static
- Dynamic

- Language communication
- Interactions
- Actions

- Mental states
- Thoughts
- Beliefs
- Desires
- Character traits
- Stereotypes
- Face identity
- Emotion
- Gaze

The Plan

Cup of coffee with people talking
The brain

The social brain

The brain

The brain

The brain

The brain

The brain

The brain
The brain

Mirror neurons

Gallese et al, report mirror neurons in macaque inferior frontal gyrus

Fogassi et al also found mirror neurons in inferior parietal lobule

What do they do?

Match different types of action
Multi-modal responses
Action goals

Macaque studies show:

Several types of mirror neuron
- Strictly congruent
- Broadly congruent
- Inhibitory MNs
Can respond to goal-less actions (Kraskov et al, 2009)

From where?

Innate?
Ferrari et al

Learnt?
Heyes et al

Before learning

After learning

In humans?

Van Overwalle et al

Single unit?
Repetition Suppression?
MVPA?
Limits of standard fMRI

- Can’t subtract actions easily – what is the right control
- Standard fMRI can’t distinguish
  - Mixture of sensory neurons + motor neurons (no MNs)
  - True MNs with sensory AND motor properties

Single units

Mukamel et al
Record single units in epilepsy patients
Sites in human SMA and parahippocampal regions
Weak mirror properties

Multi-voxel Pattern Analysis

Order doesn’t matter
Can do ROIs or whole-brain searchlight
Non-standard software

MVPA for actions

Oosterhof et al, 2009

Repetition Suppression

- Number representation (Dehaene et al)
- Object representation (Buckner et al)
- Semantic & syntactic representation (Noppeney et al)
- Performed & Observed actions (Hamilton et al)

Cross-modal RS

Kilner et al, 2009
Creating new MNs

Test Heyes claim that MNs come from assoc learning

Train shape – action association

12 blocks 150 trials (2 days)

Can’t see own hand

What does the MNS encode?

• Many ways to represent an action

  - thinks apple is good (mental state)
  - take apple (goal)
  - fingers grasp (kinematic)

Can’t separate these levels by subtraction

Infants encode goal

Woodward (1998)

Habitation Stimulus

Repeated Goal - New Trajectory

No increase in looking

New Goal – Repeated Trajectory

New Goal – New Trajectory

Increased looking

Goal repetition suppression

Novel Goal > Repeated Goal

• Left anterior intraparietal sulcus represents goal

  Hamilton & Grafton, Journal of Neuroscience, 2006
**Goals and only goals**

MNS responds to goals not actors  
Ramsey & Hamilton, NeuroImage, 2010

MNS responds equally to triangles  
Ramsey & Hamilton, Neuropsychologia, 2010

**Neural representation of grasp**

Hamilton & Grafton, Attention & Performance, 2008

**IFG is necessary for kinematics**

rTMS over IFG impairs action understanding  
Pobric & Hamilton, Current Biology, 2006

**Two levels of action understanding**

Hamilton, QIEP, 2008

**Bayesian prediction**

• Kilner et al,

**What are these action representations for?**

• Understanding?  
  – At what level?  
• Predicting?  
• Interacting?

Understand: MNS reflects what is happening now (left hand open)  
Predict: MNS anticipates what she will do next (left hand down)  
Respond: MNS prepares what I should do next (right hand grasp)
Not just watching

Second person neuroscience
Schilbach et al, BBS, in press

Shaking hands is automatic

Communicative
Gesture
Interactive
Tactual

Liepelt et al, Cog, 2010

Responding not simulating

Mimicry

• Chameleon effect

• Mimicry is modulated by – friendship / social status / desire to affiliate

• Spontaneous mimicry / imitation is reduced in autism

• How do we decide what to mimic?

Does eye contact modulate mimicry?

Direct gaze enhances mimicry

Gaze 1

F(1,19) = 10.3, p<0.005

Wang, Newport & Hamilton, Biology Letters, 2010
What brain regions are responsible?

<table>
<thead>
<tr>
<th>Response</th>
<th>Congruent</th>
<th>Incongruent</th>
<th>Catch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>CLOSE</td>
<td>CLOSE</td>
<td>BUTTON</td>
</tr>
<tr>
<td>Avoided</td>
<td>CLOSE</td>
<td>CLOSE</td>
<td>BUTTON</td>
</tr>
</tbody>
</table>

Interaction analysis

Wang, Ramsey & Hamilton, JNSci 2011

Test a model

Wang, Ramsey & Hamilton, Journal of Neuroscience, 2011

Dynamic causal modelling

Where does the interaction come from?
- mPFC or STS?

Which connection is modulated?
- input (mPFC → STS)
- intervention (STS → IFG)
- output (mPFC → IFG)

Dynamic causal modelling

Wang, Ramsey & Hamilton, Journal of Neuroscience, 2011

STORM (Social Topdown Response Modulation)

[Diagram showing social response modulation]

Wang & Hamilton, FUnH, 2012
Similar models

Cisek & Kalaska, ARN, 2010

Past experience determines strength of potential actions
Selection rules & context determine implementation

Norman & Shallice

Summary

Human mirror neuron system
• Build on associative learning
• Encodes actions at many levels
• For social responding (not just watching)
• Subject to Social-top-down modulation

Autism Spectrum Condition

Autism spectrum condition

Definitions:
• Wing’s triad (social interaction / communication / imagination)
• DSM V
  – social communication
  – repetitive behaviour

Heterogeneous
• Level of autistic symptoms
• Concurrent intellectual function

Levels of explanation

Environment

Genes
  e.g. mutation

Brain
  e.g. frontal lobes develop differently

Cognition
  e.g. inhibition deficit

Behaviour
  e.g. distractibility
Broken mirrors

- Imitation
- Goal understanding

Language system

Theory of mind system

Emotion / Empathy system

Poor Theory of Mind

Social impairment

Communication impairment

Variants

- Williams / Gallese – imitation & self other mapping
- Dapretto / Iacoboni / Oberman – simulation in general
- Rizzolatti – chaining

mu rhythms

Recorded with EEG over sensorimotor cortex

Supressed when typicals move hand or see hand movement

Rhythm is not suppressed when ASD kids watch hand action

Oberman et al, 2005

EEG mu rhythm studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Participants</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oberman, et al, 2005</td>
<td>n=11 ASC, age: 16.6 years</td>
<td>mixed</td>
</tr>
<tr>
<td>Oberman, 2008,</td>
<td>n=13 ASC, age: 10 years</td>
<td>mixed</td>
</tr>
<tr>
<td>Raymaekers, 2009,</td>
<td>n=20 ASC, age: 11.1 years</td>
<td>normal</td>
</tr>
<tr>
<td>Martineau et al, 2008</td>
<td>n=14 ASC, age: 6 years</td>
<td>abnormal</td>
</tr>
<tr>
<td>Fan et al, 2010,</td>
<td>n=20 ASC, age: 17.7 years</td>
<td>normal</td>
</tr>
<tr>
<td>Berrier et al, 2007</td>
<td>n=14 ASC, age: 23 years</td>
<td>mixed</td>
</tr>
</tbody>
</table>

TMS & EMG studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Detail</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enticott et al, 2011</td>
<td>n=34 ASC, age: 26 years. Task: observe hand or grasp</td>
<td>abnormal</td>
</tr>
<tr>
<td>Theoret et al, 2005</td>
<td>n=10 ASC, age: 39 years. Task: observe index finger or thumb movements.</td>
<td>mixed</td>
</tr>
<tr>
<td></td>
<td>Pascolo et al, 2012</td>
<td>n=7 ASC, age: 7.7 years. Task: replicate Cattaneo; record mouth muscle EMG when child grasps to eat.</td>
</tr>
</tbody>
</table>

Problems with this data

- Indirect measures of MNS function
**fMRI data**

- Dapretto et al
- 10 children with ASC (~10 years old)
- Observe / imitate emotional faces
- Differences in right IFG

**fMRI of action observation in ASD**

18 adults with ASD
19 age & IQ matched typical adults

**Normal goal responses in aIPS**

- Hands > Shapes response in left aIPS in both
- Repetition suppression for goals in aIPS for both

**fMRI studies**

<table>
<thead>
<tr>
<th>Study</th>
<th>Detail</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bastiaansen et al (2011)</td>
<td>n=21 ASC, age: 30 years. Task: observe disgusted face / move face / taste disgust;</td>
<td>mixed</td>
</tr>
<tr>
<td>Dinstein et al (2010)</td>
<td>n=13 ASC, age: 27.4 years. Task: observe / perform hand actions;</td>
<td>normal</td>
</tr>
<tr>
<td>Marsh et al (2011)</td>
<td>n=18 ASC, age: 33 years. Task: observe hand actions</td>
<td>normal</td>
</tr>
<tr>
<td>Martinot (2010)</td>
<td>n=7 ASC, age: 23 years. Task: observe / execute hand actions;</td>
<td>abnormal</td>
</tr>
<tr>
<td>Schulte-Rüther (2011)</td>
<td>n=14 ASC, age: 27 years. Task: observe emotional faces and judge self/other emotion.</td>
<td>normal</td>
</tr>
</tbody>
</table>

**Overall**

- No strong evidence for global MNS problems in autism (Hamilton, DCN, 2012).
- Where do the mixed results come from?

**STORM**

Social top-down response modulation might be abnormal
Priming by sentences

Rebel, selfish, alone, withdrawn ...

Friend, talkative, group, sharing ...

Cook & Bird, JADD 2012

Priming by emotions

Grecucci et al, JADD, 2013

Social overimitation

• Typical children imitate actions even if the action is irrational (overimitation)

• This seems to be driven by social factors.

• Do autistic children overimitate?

Participants

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Age</th>
<th>BPVS raw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autism Spectrum Disorder</td>
<td>27</td>
<td>9.01 ± 2.15</td>
<td>63 ± 20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5.2-12.7)</td>
<td>(33-119)</td>
</tr>
<tr>
<td>BPVS matched controls</td>
<td>27</td>
<td>5.85 ± 1.34</td>
<td>63 ± 20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4-8.6)</td>
<td>(35-122)</td>
</tr>
<tr>
<td>Age Matched Controls</td>
<td>27</td>
<td>8.95 ± 2.11</td>
<td>93 ± 20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.9-12.7)</td>
<td>(57-137)</td>
</tr>
</tbody>
</table>

Task

5 trials, each has 2 rational + 1 irrational action

Measures:

• Does the child overimitate?
• Does the child rate the action as sensible or silly?

Video here ...
Amount of over-imitation

All children imitated all necessary steps of the action correctly

Rationality Ratings

Why a difference?

• Reduced social motivation?
  – less desire to affiliate
  – less desire to conform to social norm
  – less knowledge of how to affiliate / conform

• What brain systems?

fMRI of action observation in ASD

18 adults with ASD
19 age & IQ matched typical adults

Normal goal responses in aIPS

Repetition suppression for goals in aIPS for both

Observation of irrational action in autism

Marsh et al, Curr Biol, in press

Marsh et al, Curr Biol, in press
Brain systems in autism

STORM in autism

How can we test this?

Thank you