Understanding Others
From Dots to Robots

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Understanding Others
Understanding Others

Theory
3rd person ("other") actions: Often visually perceived
1st person ("self") actions: Rarely visually perceived
Yet we are able to know what we perceive (Barresi & Moore, 1996, BBS)

Neuroscience

Visual hypothesis – Based on a visual analysis of the elements (body parts, objects, motion, etc). No sensorimotor involvement is required

Simulation hypothesis – Analysis-by-synthesis. We map the visual representation onto our own sensorimotor representations
Perception and Action

motor planning and execution
decision-making and other
“executive functions”
Perception and Action

Frontal and posterior cortical regions are heavily interconnected.
Mirror Neurons

Frontal area F5 in the macaque (Rizzolatti lab, ca 1996)
Later also found in parietal cortex

Neuroimaging in humans: The mirror neuron system
Inferior frontal cortex
Inferior parietal cortex
Superior temporal sulcus (STS)
(Umilta et al., 2001, Neuron)
Other findings

Mirror neurons are not specific to vision
Auditory mirror neurons in monkey

Kohler et al., 2002, Science
Theory

An individual can understand others’ actions by mapping the visual representation of the observed action onto his/her sensorimotor representation of the same action, thus using his/her own embodied experience of the world.

“An action is understood when its observation causes the motor system of the observer to ‘resonate’” (Rizzolatti, Fogassi, & Gallese, 2001).
Point-light Biological Motion

Grossman & Blake
Motion-defined actions

Given that point-light biological motion figures give rise to vivid action percepts, are they also processed in action-related areas - e.g. premotor/IFG?
Motion-defined actions

Given that point-light biological motion figures give rise to vivid action percepts, are they also processed in action-related areas - e.g. premotor/IFG?

Or are they mainly processed in motion-sensitive areas?
**Functional MRI**

NMR technology

**BOLD signal:** Measures the haemodynamic response related to neural activity (sort of...)

Oxy/deoxy hemoglobin

Excellent spatial, poor temporal resolution

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One high resolution (anatomical) image

Many low resolution (functional) images
The Scanner

Magnetic: Static Magnetic Field Coils
Resonance: Radiofrequency Coil
Imaging: Gradient Field Coils

Shimming Coils
Data transfer and storage computers
Physiological monitoring, stimulus display, and behavioral recording hardware
The Scanner
How It Works

**Magnetic:** Put subject in strong magnetic field

**Resonance:** Transmit radio waves, turn off transmitter, receive radio waves emitted by subject’s brain (the MR signal)

**Imaging:** Modulate the strength of the magnetic field slightly over space

$B_0$ is the scanner’s main field.
MRI: Magnetic: Magnet: Means: NO Metal!
Analysis

MAGIC

SPM: www.fil.ion.ucl.ac.uk
fMRI Study


Dale, Fischl & Sereno, 1999; Fischl, Sereno & Dale, 1999
Biological Motion Vs. Scrambled

Lateral Temporal Cortex
  pSTS, V5/MT+, (EBA, LOC) / BA 37, 39, 22

Inferior Frontal Cortex
  Inf. Frontal Sulcus and Precentral Sulcus / BA 44, 45, 6

From Saygin et al, 2004 J Neurosci
Possible Cross-Species Difference

Human mirror system (frontal) responds to simplified representations such as point-light actions.

Macaque mirror neurons do not respond to point lights, or even respond to videos...

Monkey -> Human: Abstract representation of actions are also OK?
fMRI Results

Biological motion activates premotor/inferior frontal cortex.
Indeed, IF and premotor areas are just as selective as pSTS.
Cross-Species Differences

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Language and Mirror Neurons

Inferior frontal gyrus - Broca’s area
Although language regions tend to be more inferior and anterior, there is some overlap
Mirror neurons - origins of language?
Motor theory of speech perception

Liberman et al. 1967
Auditory signals too variable
Motor representations are used in perception of speech

Nice idea but there was no evidence
- Categorical perception: /da/ or /ta/ not between
- But also chinchillas, birds, macaques (e.g., Kuhl & Miller, 1975)
Listening to and producing speech

UCLA/UCSD Study

Listen to monosyllables /pa/ /gi/
Produce monosyllables /pa/ /gi/

Overlap found.
Note: This is a more superior area than Broca’s area.

Language Semantics

Foot action words
Hand action words
Mouth action words
Somatotopy

Hauk, et al., 2004, Neuron
Empathy for pain

Not in primary sensory cortex but in affective pain processing areas.

Singer et al., 2004, Science
Back to biological motion

Are these areas necessary for biological motion perception?
Neuropsychological Study

Saygin AP (2007) *Brain*

47 LHD patients, 13 RHD patients, 18 age-matched controls

- Normal or corrected to normal vision
- Patients >1 year post onset of stroke
- Unselected lesion site - but single infarct, unilateral lesion
- No other neurological conditions
Stimuli and Task

Biomotion: 7 action animations
Stimuli and Task

Biomotion: 7 action animations

Scrambled biomotion - 2AFC
Detect point-light biological motion in noise, 2AFC
Behavioral measure: Number of noise dots at 82% accuracy
Adaptive estimation with QUEST (Watson & Pelli, 1983)
Behavioural Results

Both LHD and RHD patients significantly impaired.

Controls > LHD p<0.0001
Controls > RHD p<0.01
RHD, LHD n.s. p=0.7

From Saygin, 2007 Brain
VLSM: Voxel-Based Lesion Symptom Mapping


Dronkers, Wilkins, Van Valin, Redfern & Jaeger, 2005, *Cognition*
### VLSM

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<th>Lesion</th>
<th>Behaviour</th>
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A Given Voxel

Each patient's lesion either includes or excludes voxel

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Each patient’s lesion either includes or excludes voxel

Each patient has behavioural measure(s)

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A Given Voxel

Each patient’s lesion either includes or excludes voxel
Each patient has behavioural measure(s)
Compare Intact and Lesioned and get a statistic (eg, $t$, $p$)
Biological Motion: Lesion Map

Map of the t-statistic at each voxel

Large region in temporal and parietal cortex (BA 21, 22, 37, 39, 40)
Smaller area in inferior frontal gyrus (BA 44, 45, 6)

From Saygin, 2007 Brain
Lesion Independence

ANCOVA map: Frontal and posterior lesion sites are independent from each other

From Saygin, 2007 Brain
Lesion and fMRI Results

FROM SAYGIN, 2007 Brain
Lesion and fMRI Results

From Saygin, 2007 Brain
Motion cues sufficient to drive premotor areas
These regions are both involved in and necessary for biological motion perception
Do Looks Matter?
Do Looks Matter?

Less resonance  More resonance

Buccino et al, 2004
Humanoid Robots

Robotic agents: Can perform recognisable actions but do not have true biological motion
Appearance can be more or less human-like
An opportunity to test selectivity of the action perception system for human movement and/or human appearance

Also relevant to robotics
Interactive robots: Retail, healthcare, education...
But what kind of robots should be made?

Wall-E, 2008, Pixar
Humanoid Robots

Conflicting results re: robot actors
e.g., Gazzola et al 2007; Kilner et al 2003; Oberman et al 2007;

We used state of the art robots
Plus manipulated the appearance of the robots
Humanoid Robots and Androids
The Uncanny Valley

Mori, 1970

Humanlikeness is not always “good”

Framework - not based on experimental data
Repliee-Q2 was developed at Osaka University in collaboration with Kokoro Co.
Repliee-Q2 as Humanoid Robot
Stimuli

Actions by:

Human (master of Repliee-Q2)
Android (Repliee-Q2)
Robot (made from Android)

Grasping, wiping, picking up, nodding, waving, yawning...

All video-ed using same camera, objects, background at Intelligent Robotics Lab, Osaka, Japan
Appearance and Motion

Nonhuman appearance
Nonhuman motion

Human appearance
Nonhuman motion

Human appearance
Human motion
Appearance and Motion

Nonhuman appearance
Nonhuman motion

Human appearance
Nonhuman motion

Human appearance
Human motion
Appearance and Motion

Nonhuman appearance
Nonhuman motion
MATCH between appearance and motion

Human appearance
Nonhuman motion
MISMATCH between appearance and motion

Human appearance
Human motion
MATCH between appearance and motion
Repetition Suppression

Neuronal adaptation - less response to repeated feature
Reduced fMRI response in regions coding repeated property
Repetition Suppression

Neuronal adaptation - less response to repeated feature
Reduced fMRI response in regions coding repeated property
Here same or different action (cf. Dinstein et al, 2007; Hamilton & Grafton, 2006, 2008; Lestou et al, 2008)

Same < Different  = Repetition Suppression
Agent (3) x Repetition (2)

Interaction?

NEW
- Robot New
- Android New
- Human New

REPEATED
- Robot Rep
- Android Rep
- Human Rep
Uncanny Hills in the Brain?
Temporal Cortex

INTERACTION (A>R, H>R) in Left Hemisphere

EBA, V5/MT+, pSTG/STS (BA 37, 21, 22)
Parietal Cortex
INTERACTION (A>H A>R) in Bilateral aIPS

pIPS (BA 19)  aIPS (BA 7, 40)  pIPS (BA 19)  aIPS (BA 7, 40)
Appearance and Motion

Temporal cortex by appearance (likely EBA)
Parietal cortex by mismatch in appearance and motion

No evidence for selectivity for human appearance or biological movement in frontal and parietal

It’s not biological movement or appearance per se...

Interaction/integration of appearance and movement

Uncanny valley: Processing conflict in the action perception network
Predictive Coding

Hierarchical system. Brain tries to minimize prediction error

Human and Robot
- Match between appearance and movement
- Correct model can be selected from appearance

Android
- Appears human
- Attempt to use human model
- Kinematics not as expected
- Prediction error
Future Work

This is just a start

More continuous modulation of appearance and movement (e.g. animation)

Methods more appropriate to study dynamics of the network (EEG, MEG, TMS)
Future Work

Turing Test (Turing, 1950, Saygin et al, 2000) - Can a computer pass for a human?

Total Turing Test (Harnad, 1989) - Must be a robot

A Neural Turing Test?
Is the brain response to robot indistinguishable from that for a real human?
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Thank you!