Disentangling Embodiment

A Question
- Do the mental states of the self-sensing XOR robot supervene on a linearly-separable space of neural activations?

Logical Relations
- AND (A and B)
- OR (A or B or both A and B)
- XOR (exclusive or; A or B, but NOT both)

Truth Table Representation

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>A OR B</th>
<th>A AND B</th>
<th>A XOR B</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>T</td>
<td>T</td>
<td>F</td>
<td>T</td>
</tr>
<tr>
<td>T</td>
<td>F</td>
<td>T</td>
<td>F</td>
<td>T</td>
</tr>
<tr>
<td>T</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>F</td>
</tr>
</tbody>
</table>

Change representation
- A = X
- B = Y
- T = 1
- F = 0

We can now express the truth table as points in space.

Cartesian Space

We can visualize the truth table as points in a 2D space, where each point corresponds to a row in the truth table.

- (0, 0) corresponds to A = F and B = F.
- (0, 1) corresponds to A = F and B = T.
- (1, 0) corresponds to A = T and B = F.
- (1, 1) corresponds to A = T and B = T.
A simple perceptron

A network that can compute XOR (not a perceptron)

A Robot that Computes Exclusive Or (XOR)
Supervenience

- If psychological properties supervise on physical properties, then any two persons who are physically indistinguishable must also be psychologically indistinguishable; or equivalently, any two persons who are psychologically different (e.g., having different thoughts), must be physically different as well. (wikipedia)

Answer to the question

- Do the mental states of the self-sensing XOR robot supervene on a linearly-separable space of neural activations?
- NO, because
  - XOR is not a linearly separable function
  - And because the mental states supervene on the brain-body system, not the neural activations alone.

Why embodiment matters (pg 196)

- Spread the load
- Self-structuring information
- Supporting extended cognition
- Hypothesis of cognitive impartiality
- Hypothesis of motor deference

Dawkin’s flip

The science yet to do

- To unravel the workings of these embodied, embedded, and sometimes extended minds requires an unusual mix of neuroscience, computational, dynamic and information-theoretic understandings, “brute” physiology, ecological sensitivity, and attention to the stacked designer cocoons in which we grow, work, think, and act. (SM: 219)
Making American Boys

Making American Girls

Everyday Brain Computer Interface

Experimental analysis of three enacted representations

- Thrombin hand
- Sheared brain
- That 'n that

Enacted representations

- representation is the activity of bring forth the thing represented,

- Just as perception and action are linked, so imagination and action are linked. To imagine something is to bring it forth through an activity.
Parts of enacted representations

• A culturally meaningful image
  – embedded in an activity
  – such that participants
  – experience a question or problem
• An embodied action
  – coupled to the image
  – in a way that suggests an answer or solution
• An utterance
  – that is coordinated with the embodied action (via timing and indexicals)

• A stream of gesture that is coupled to the image in a way that suggests an answer to a question or a solution to a problem.

Parts of enacted representations

• A culturally meaningful object
  – embedded in an activity
  – such that participants
  – experience a question or problem
• An embodied action
  – coupled to the object
  – in a way that suggests an answer or solution
• An utterance
  – that is coordinated with the embodied action (via timing and indexicals)

• An utterance that is coordinated with the embodied actions such that the meaning of talk and the meaning of embodied actions mutually elaborate each other.