Learnus™

Understanding Learning
www.learnus.co.uk

"Understanding Learning – is it all in the brain?"

Mediated Workshop

Tuesday 15th October 2013

Nunn Hall, Institute of Education

The Science and Art of Reasoning

Denis Mareschal
Centre for Brain and Cognitive Development
Birkbeck University of London

What is Reasoning?

- Mental activities that are involved when individuals attempt to make discoveries about the world… to increase knowledge
- Occurs either (1) through deduction, or (2) observation, abstraction and generalisation
- Same cognitive operations that humans used in many domains, such as science and math, but also text comprehension, history and everyday problem solving

The Classic View: Piaget & Logic

- Piaget focussed on the development of reasoning (i.e., logic) and the origins of knowledge
- He proposed the quintessential stage theory: Qualitative changes, concurrence, abruptness
- Sensori-motor stage (0-2 years)
- Preoperational stage (2-6)
- Concrete operational stage (7-11)
- Formal operational stage (12 onwards)

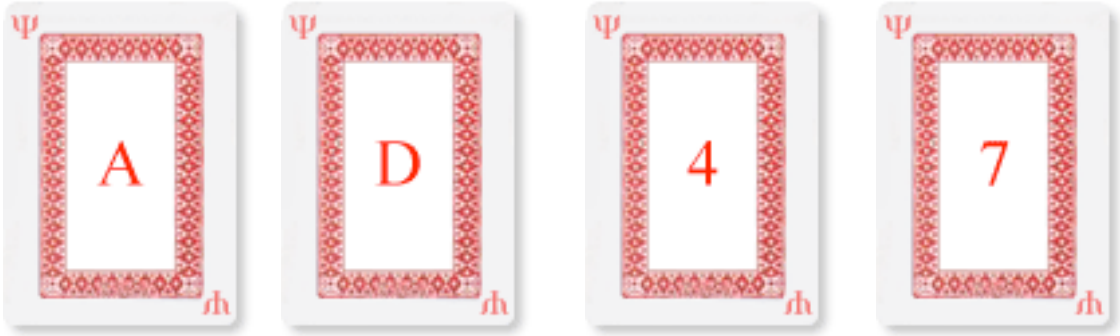
The Classic View: Piaget & Logic

- Piaget focussed on the development of reasoning (I.e., logic) and the origins of knowledge
- He proposed the quintessential stage theory: Qualitative changes, concurrence, abruptness
- Sensori-motor stage (0-2 years)
- Preoperational stage (2-6)
- Concrete operational stage (7-11)
- Formal operational stage (12 onwards)

BUT HOW LOGICAL ARE WE REALLY?

Knowledge-Based Inference

1. The Wason Card Task

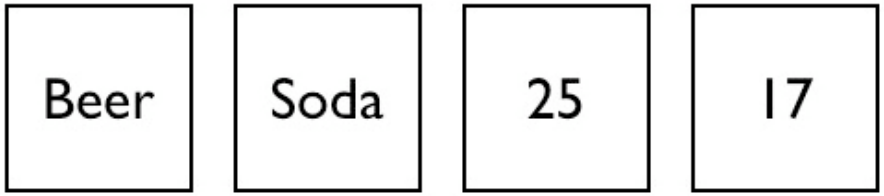


"If a card has a vowel on one side, then it has an even number on the other side"

Which cards do you turn over to verify this?

Knowledge-Based Inference

1. The Wason Card Task



"If you are drinking alcohol, then you must be over 21"

Which cards to you turn over to verify this?

Knowledge-Based Inference

2. Affirming the consequent

All mammals have fur
Wombats have fur
therefore…

Wombats are mammals

Do you find this compelling?

Knowledge-Based Inference

2. Affirming the consequent

All mammals have fur
Wombats have fur
therefore…

Wombats are mammals

Do you find this compelling?

Well it is wrong! There may be other kinds of animals with fur.

Knowledge-Based Inference

3. Non-computable inferences

Some dogs are brown

Some dogs have stripes

THEREFORE……???

Knowledge Based Inference

3. Non computable inferences

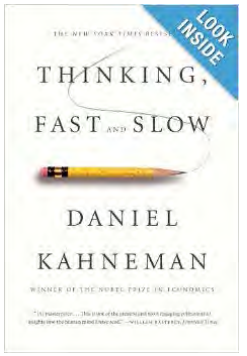
Some dogs are brown

Some dogs have stripes

THEREFORE……???

Many people would conclude that some dogs are brown with stripes, but this is not deductively valid!

Knowledge Based Inference



YES… we CAN use logic but this is hard

Most reasoning is quick and dirty (Kahneman)

Relies on extensive use of knowledge and short-cuts (heuristics)

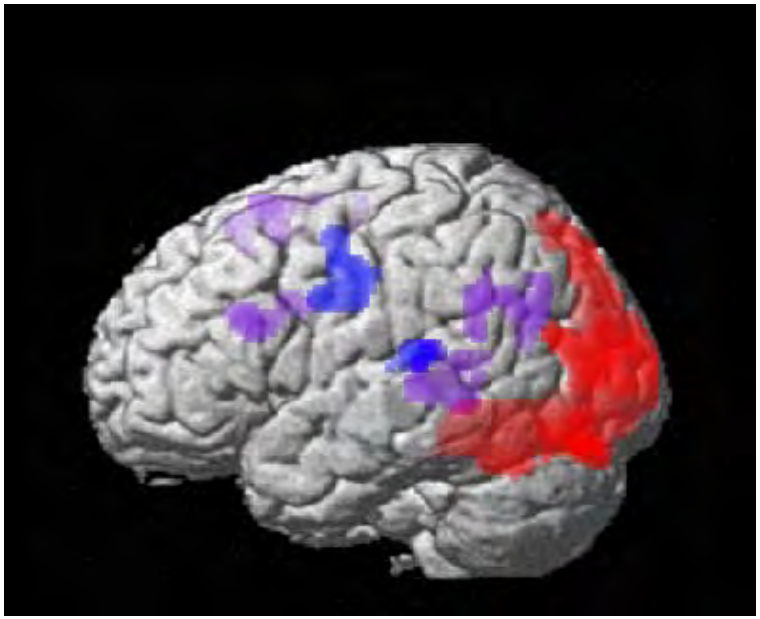
Statistical inference underlies reasoning (we guess what is most “likely” given past experience) (Chater & Oaksford)

Statistics is the “language of the brain”

Exploring Reasoning in the Brain

Functional imaging (e.g. fMRI) measures "current processing" *within an individual*

Structural images appear to reflect: "learning" "ability" possibly "potential" differences ***across individuals***



Exploring Reasoning in the Brain

- Almost all work carried out with adolescents and young adults

- Difficulties of working with children include noise, motion artefacts, lack of structural templates.

- Lowest ages typically 6 years of age

Three Examples….

- **Deductive inference**

E.g., all mammals have fur. Wombats are mammals, therefore wombats have fur

- **Causal inference**

Increased atmospheric CO2 output causes global warming

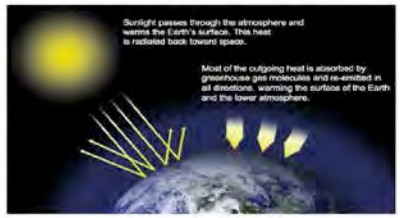


Figure 1 (source: http://climate.nasa.gov/causes)

- **Analogical inference**

E.g., Rutherford Atom ⇔ Solar Syste

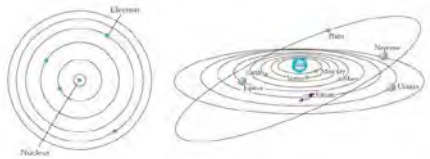
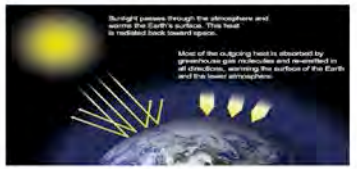
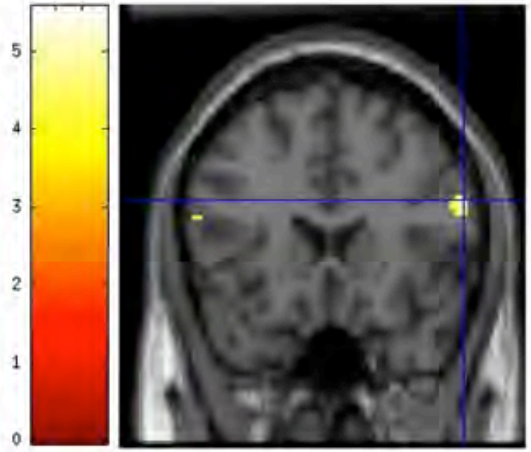
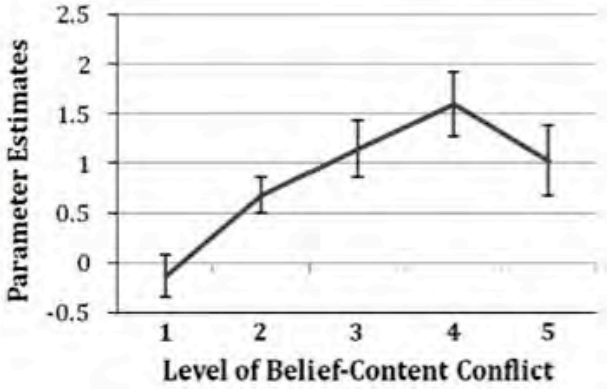


Figure 5 (Source: Galotti, Fernandes, Fugelsang, & Stolz, 2010; *Nelson Publishing*)

Deductive Inference in the Brain







Greater activation of DLPFC with greater level knowledge conflict

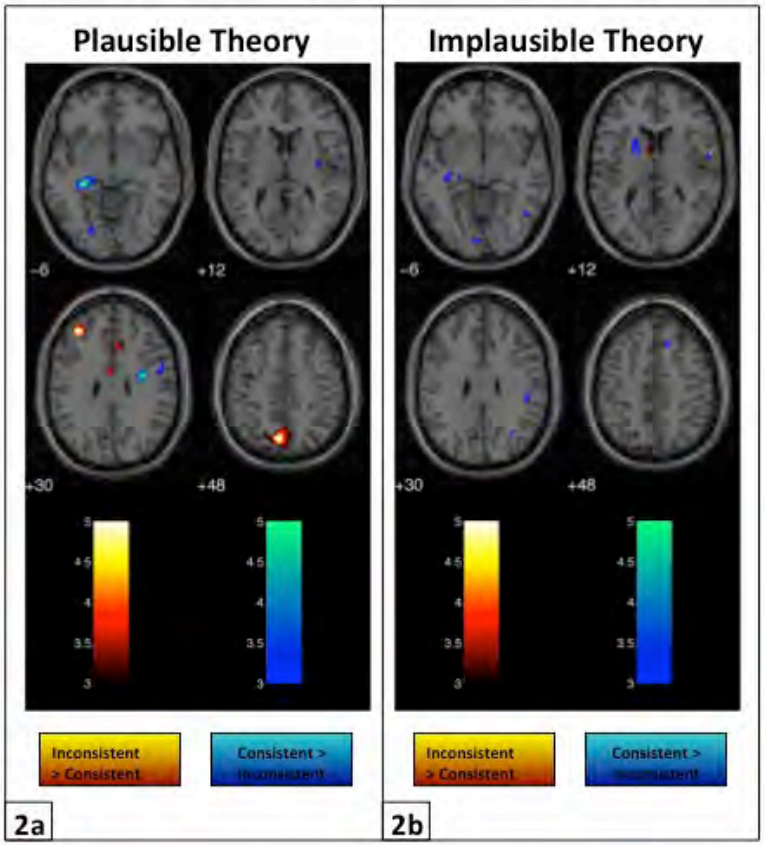
Figure 4 (Source: Stollstorf, Vartanian, & Goel, 2012; *Brain Research*)

Deductive Inference in the Brain

- Imaging suggests that both language-based and visual spatial modes are engaged during deductive reasoning (Goel, 2007, 2003)
- A fractionated system that can be dynamically reconfigured in response to the familiarity of the task

- Implication of DLPFC (Dorsal Lateral Prefrontal Cortex) … especially in tasks involving the integration of prior knowledge

Causal Inference in the Brain



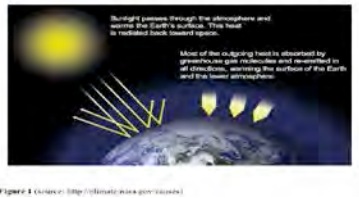
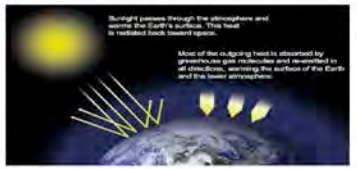


Figure 2 (Source: Fugelsang & Dunbar, 2005; *Neuropsychologia*)

Different patterns of activation when making consistent vs. inconsistent inference

Causal Inference in the Brain

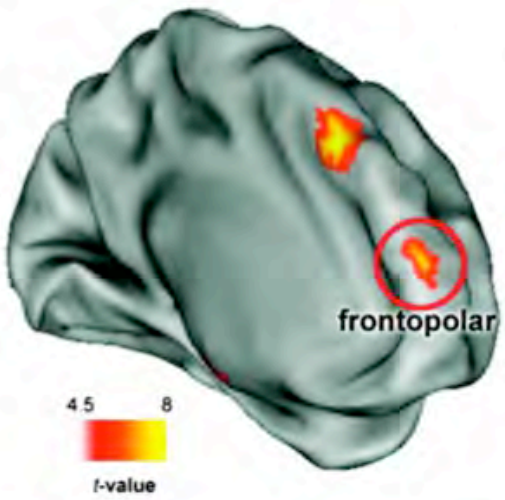


- Few studies of causal reasoning (Fugelsang & Dunbar, 2005)
- Different systems underlie causal perception from causal reasoning
- Evaluating causal explanations recruited :

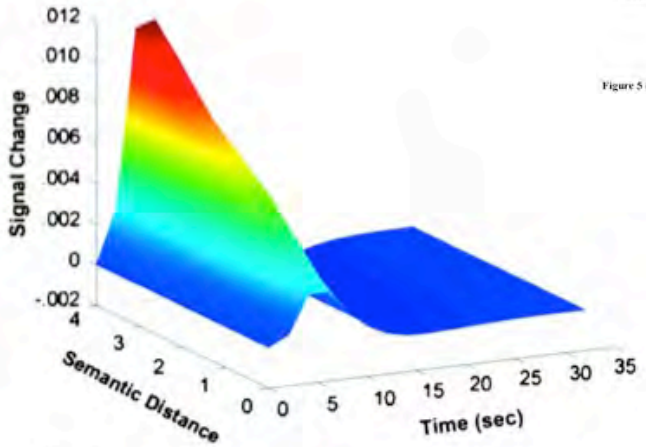
(1) parts of the parahippocampal cortex (associated with semantic knowledge) when the explanation was consistent with prior beliefs

(2) the DLFPC (Dorsal Lateral Prefrontal Cortex) and Anterior Cingulate (AC) when hypothesis was inconsistent with prior beliefs

Analogical Inference in the Brain



6a



6b

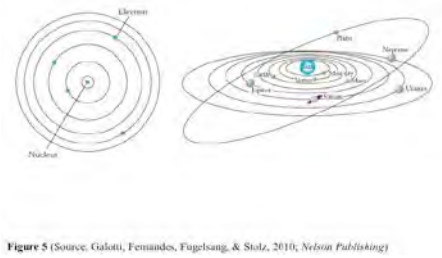


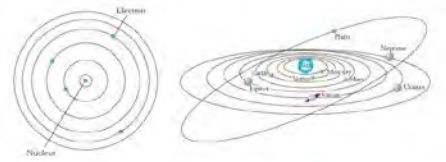
Figure 5 (Source: Galotti, Fernandes, Fugelsang, & Stolz, 2010; *Nelson Publishing*)

kitten:cat::spark:fire
kitten:cat::puppy:dog

Figure 6 (Source: Green, Kraemer, Fugelsang, Gray, & Dunbar, 2010; *Cerebral Cortex*)

Greater semantic distance implied greater activation

Analogical Inference in the Brain



- Some studies with children from age 8 years.
- Need to differentiate perceptual from verbal analogies
- Evaluating or producing analogies revealed that:

(1) Frontopolar cortex (part of the PFC) and right lateral PFC are sensitive to integration of multiple systems of relations (either abstract or concrete)

(2) Children engage similar systems but do so too late to influence response, or not at all if there is too much relational complexity.

Key ideas…

- Findings are consistent with the idea that executive functions can be dissociated into *Evaluative* and *Executive* components involving the AC and DLPFC respectively

- AC identifies conflict and DLPFC resolves conflict

- Few developmental fMRI studies
- BUT findings are consistent with the suggestion of the importance of conflict monitoring in classic theories of reasoning (e.g., Piaget's reflective abstraction)

General Lessons from Neuroimaging…

- Fractionated generalist systems made from basic cognitive building blocks
- Both *executive control* and *semantic knowledge* systems play an important role in reasoning
- Reasoning that is consistent with prior knowledge recruits different a neural system than reasoning that is inconsistent with prior knowledge
- The late maturing of the DLPFC may partially underlie prolonged development of reasoning skills

Putative Implications for Education

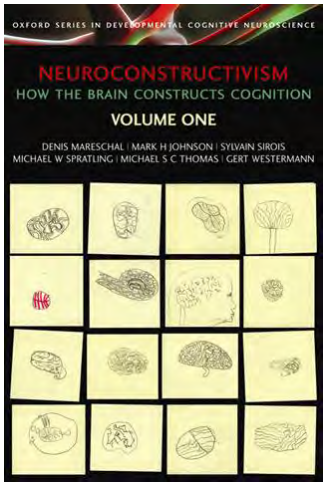
- Participants engage different reasoning systems when presented with hypotheses consistent or inconsistent with prior beliefs or knowledge

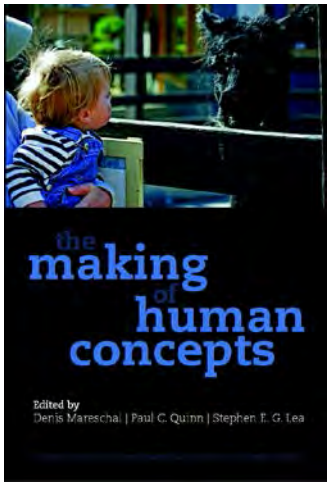
(1) So… increasing domain knowledge should be a pre-cursor to teaching inferential techniques (e.g., hypothesis testing)

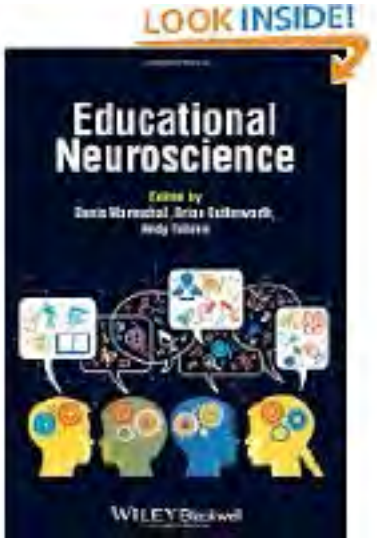
(2) Improving "conflict monitoring" will have knock-on effects on reasoning in the brain

More developmental research needed!

Thank you for your attention!







WANT TO GET INVOLVED IN RESEARCH…????

EMAIL US AT Hayley.White@bbk.ac.uk

RESEARCH CAN ONLY PROGRESS WITH THE KIND PARTICIPATION OF VOULNTEERS!