WHAT IS DUAL IN DUAL PROCESS THEORY?

Interpreting neural data in favor of a dual process theory of reasoning

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The Question

- Our basic problem is to address the question as to how deeply it is necessary to seek for evidence in favor of one (or another) dual process theory of reasoning.

- Some researchers, in particular V. Goel, have addressed this question seriously since they have run experiments that provide us with brain-imaging data that one can try to interpret as supporting a dual process theory of reasoning.

- In the following we discuss rival interpretations of these neural data, suggest an interpretation thereof which is not couched in terms of a dual process theory, and eventually propose a crucial experiment from a neuropsychological point of view.

Outline

1. Two contrasts in Goel's Results

2. Discussing the two contrasts

3. A case in numerical cognition

4. An alternative interpretation of Goel's results

1. Two contrasts in Goel's Results

1. Two comparisons in Goel's studies

- Comparison 1: Between the evaluation of arguments based upon familiar situations and the evaluation of arguments based upon unfamiliar situations.
  - (a) abstract versus belief-based syllogisms (Goel et al., 2000)
  - (b) belief neutral versus belief based syllogisms (Goel & Dolan, 2003)
  - (c) transitive arguments based on unfamiliar spatial content versus familiar spatial content (Goel et al., 2004)
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- Comparison 2: Among belief-based arguments, between the correct answers & the wrong answers.

Comparison 1: Content based versus abstract based arguments

- Content based
  - All poodles are pets
  - All pets have names
  - All poodles have names
- Abstract based
  - All A are B
  - All B are C
  - All C are B

Comparison 1: Belief laden versus belief neutral arguments

- Belief laden
  - Some green amphibians are toads
  - All green amphibians are frogs
  - Some frogs are toads
- Belief neutral
  - Some monorchids are ground rhumbs
  - All ground rhumbs are rare
  - Some monorchids are not rare

Comparison 1: Transitive arguments in familiar vs unfamiliar spatial environment

- Familiar environment
  - Spain is West of Italy
  - Italy is West of Greece
  - Spain is West of Greece
- Unfamiliar environment
  - Cedar Hall is West of Roth Centre
  - Roth Centre is West of the AI lab
  - Cedar Hall is West of the AI lab

Contrast 1

- Comparison 1: a contrast in neural activity is observed:

- Contrast 1: between the neural activity associated with reasoning in unfamiliar situations & the activity associated with reasoning in familiar situations.
  - Observed when only correct answers are taken into account and performance is roughly equivalent in all cases.

- (a) abstract versus belief-based arguments
  - Bilateral parietal network vs left temporal network.
- (b) belief-neutral versus belief based arguments
  - Bilateral parietal network vs left temporal network.
- (c) transitive arguments based on unfamiliar spatial content versus familiar spatial content
  - Bilateral parietal-dorsal & medial frontal network vs
    Frontal orbital-occipital-temporal & hippocampus network

Contrast 2

- Arguments subject to the belief bias (valid argument with false conclusion or invalid argument with true conclusion)
  - Correct answers vs incorrect answers
  - Dorso-lateral prefrontal cortex vs ventro-medial prefrontal cortex.

Interpretation of contrast 1 according to dual process theories of reasoning

- There are 2 reasoning systems implemented in the brain, these 2 systems correspond to the duality System I/System II.

Contrast 1

- Contrast 1
  - "The frontal-temporal pathway corresponds to the "heuristic" system [system 1] while the parietal pathway corresponds to the "universal" system [system 2]. Reasoning about familiar situations automatically utilizes situation-specific heuristics, which are based on background knowledge and experience. Where no such heuristics are available (as in reasoning about unfamiliar situations), universal/formal methods must be used to solve the problem." (Goel, 2003).

2. Discussing Contrast 1

3 possible positions on logical competence

- Position 1
  - One single logical competence implemented in a single cerebral pathway
- Position 2
  - Two distinct competences respectively implemented in distinct cerebral pathways (Dual process theories of reasoning)
- Position 3
  - One single logical competence implemented in distinct cerebral pathways depending on the context/content of the task.

Goel's results regarding position 1

- Goel's results do not seem consistent with position 1.
- But, we may argue that Goel's contrast only shows the difference in processing the mental representations (numbers, concepts, letters…) involved in familiar and unfamiliar situations. The contrast has nothing to do with differences in the reasoning process itself.

Goel's results regarding position 2 (1)

- There are some reasons to think that these results do not support position 2.

- (1) No difference in performance:
  - If Ss answer according to their beliefs in familiar situations (syst 1) but not in abstract situations (syst 2), then performance should be significantly superior in familiar situations. But the performance is similar in both situations (79% vs 77,3%).

- (2) Reaction Time:
  - If the familiar task is processed by System 1, then it should be significantly faster to solve this task than to solve the abstract one, however it does not seem to be the case.

Goel's results regarding position 2 (2)

- (3) Biases in abstract situations:
  - Reasoning in abstract situations does not mean using system 2 (ex: figural effect, Dickstein, 1978).
- (4) Taking errors into account:
  - What is the neural activity correlated with errors in the abstract version of the task?

Goel's results regarding position 3

- Against position 3:
  - Alternative task construal: In familiar situations, Ss answers according to their beliefs regarding the truth value of the conclusion. Thus, Ss perform another task.
- But Goel's results may support position 3:
  - There would be a unique reasoning competence which is implemented in different neural substrates according to the type of representations which are processed.

3. A case in numerical cognition

A Case in Numerical Cognition (Dehaene & Cohen, 1997)

- Dissociation in the neural correlates of a number bisection task depending on the context (familiar vs abstract) of the task.
- MAR has a lesion in the right inferior parietal lobe

MAR's abilities

- Task: When presented visually with a pair of arabic numerals, MAR is asked to produce orally the number which falls in the middle of the interval.
  - Ex: What falls between 2 and 4? / error rate: 77,4 %

- However, MAR is able to perform the same task in some familiar situations, for example when the numbers are used to refer to hours.
  - Ex: what falls between 2 PM and 4 PM?

Interpretation of MAR's case

- There is no misunderstanding of the task
- MAR's deficit is limited to abstract numbers
- Interpretation 1:
  - The bisection competence is independent of the context. MAR is not impaired because of a degradation of his bisection competence but rather because the brain region used by his representation of abstract numbers is damaged.
- Interpretation 2
  - The bisection ability is not independent of the context, but rather it is realized in different neural substrates depending on the context.

4. Alternative interpretations of Goel's results

Discussion

- As in MAR's interpretation 1:
  - Goel's contrast can be explained by the difference in the mental representations involved by the different contents (capital letters, familiar words, familiar environments…) of the tasks.
  - There is a mechanism dedicated to the recognition of a valid argument which is independent of the content evoked by the task.
  - This is Position 1

- As in MAR's interpretation 2:
  - The recognition of the validity of an argument is realized by different cognitive and neural processes depending on the content expressed by the task.
  - This is Position 3

Question

If there are different neural circuits that underpin a mechanism dedicated to deductive reasoning, are there any patients who, on a par with MAR, would be impaired in their capacity to recognize the validity of an inference only in some particular contexts?

Proposal

- A possible way to test both hypotheses H1 “contrast 1 supports Position 2” and H2 “contrast 1 supports Position 3” .

- 2 brain damaged patients with the following lesions:
  - Patient X has a lesion in the left temporal lobe (in particular the hippocampus, claimed to be the neural basis of cognitive maps) but no lesion in the parietal lobes
  - Patient Y has a bilateral parietal lesion (in particular BA 7) and no lesion in the hippocampus.

Testing H1

- If H1 is true, (Position 2: subjects use heuristics while performing reasoning based on familiar content) then:
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  - if patient X is not impaired in the abstract task, he will not be impaired in the familiar task.
  - He is not able to use the heuristics but he should be able to perform reasoning.
  - On the other hand patient Y should be impaired in the abstract task but not in the familiar task.

Testing H2

- If H2 is true (i.e. position 3) then :
  - patient X will fail to belief-based tasks but not to abstract tasks while patient Y will fail in the reverse way.
  - This would be a double dissociation and the criterion responsible for the shift in brain activity between the two versions of the tasks is the domain of content and not the heuristic.