

Categorizing Students' Mental Representation during Problem Solving of different Representational Task Formats

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*NARST conference
25th - 28th March 2012
Indianapolis, Indiana.*



Visualization

Internal representation



...form images **mentally**; **paper and pencil** or **technology**



External representation

(Zimmermann & Cunningham, 1991)

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Relationship between Internal and External Representation

- ❑ External representation used to:
 - promote generation of cognitive construct,
 - support understanding.

- ❑ Inhibitors of links between two kinds of representations:
 - quality of external representation,
 - lack of content knowledge,
 - superficial cognitive engagement.

(Greca & Moreira, 2000; Schnotz & Bannert, 2003; Ainsworth, 2006; Gobert, 2007; Rapp, 2007)

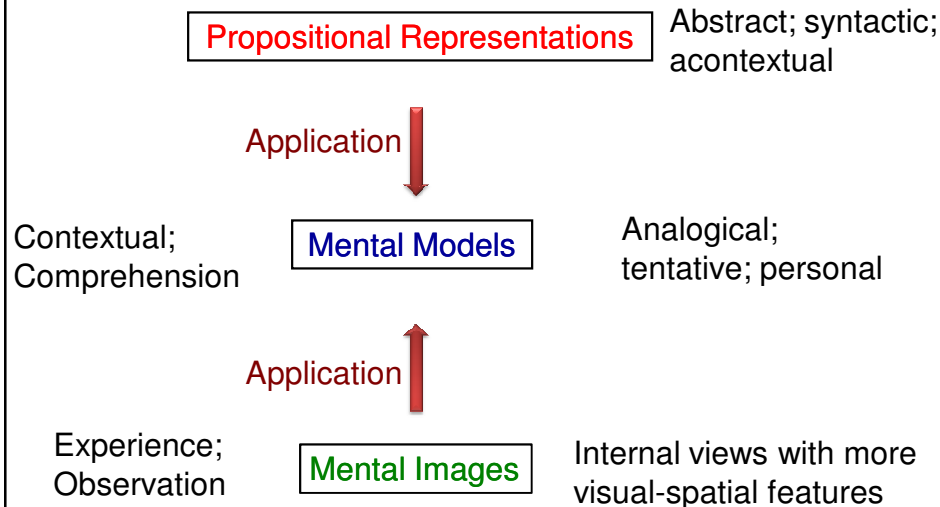
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Research Question

At what level of internal representation do students operate when solving problems with different external representational formats?

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Johnson-Laird (1983) Cognitive Framework



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Method

- 19 engineering students; calculus-based physics course.
- Two individual interview sessions; 1 hour each.
- In each session:
 - Solve **non-directed** tasks from topic on **work**
 - Probe about their problem solving strategies, e.g.
 - Why did you use this strategy?
 - Are there any other strategies to solve the problem?
 - What is the purpose of the visual representation?

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Method (cont'd)

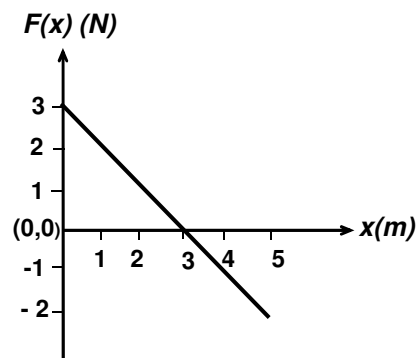
Types of Tasks & Solutions

		Tasks		
		Graphical	Symbolic	Linguistic
Solutions	Qualitative	√	√	
	Quantitative	√	√	√

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Example : Graphical Task Qualitative Solution

Write down everything you can say from the graph when a box is moved from an initial position of 0 m to final position of 5 m.



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Example : Symbolic Task, Quantitative Solution

The force applied in moving a 5kg box on a frictionless horizontal surface is given by

$$\vec{F}(x) = (3x - 2) \hat{i} \text{ N.}$$

Determine the work done in moving the box to a distance of 5m if its initial position is 1m.

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Analysis: Profiling

1. Identify frequently occurring combinations of problem solving strategies across the tasks for each participant.
2. Construct written descriptions (profiles) to capture essence of different strategies used:
 - Descriptors refined.
 - Two main profiles emerged.

(Ibrahim, Buffler & Lubben, 2009)

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Analysis: Profiling (cont'd)

3. Assign each student to one of these profiles
 - Inter-rater reliability 85%.
4. Relate profiles to Johnson – Laird framework to infer kind of mental representations:

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Analysis: Relate Profiles to Framework

- ❑ **Propositional Representation :**
 - focus on structural or symbolic aspects of representation,
 - prioritize equations; use rote memorization; pattern match.
- ❑ **Mental Model :**
 - derive physics information,
 - include and use visual representation.
- ❑ **Mental Image :**
 - generate visual representations but ignore from equation,
 - aware of qualitative reasoning but prefer equations.

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Results

- **Propositional Representation**
 - 15 in 19 students:
- **Mental Model**
 - 4 in 19 students:
- **Mental Image**
 - No students

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Results

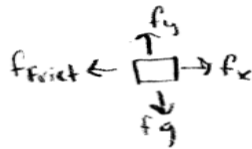
Profile: Propositional Representations Descriptors of Actions

	Symbolic	Graphical	Linguistic
Qualitative	Describe surface features, apparent information		
Quantitative	Use equations; unaware of graphical strategy	Use graph mechanically; or use memorized equations	May include diagram; ignore it while using equations

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Example : Propositional Representation

Linguistic Task, Quantitative Solution



$$\begin{aligned}
 m &= 10 \text{ kg} \\
 \Delta d &= 15 \text{ m} \\
 F &= 20 \text{ N} \\
 \theta &= 30^\circ \\
 \mu_k &= .25
 \end{aligned}$$

$$\begin{aligned}
 W &= F \cdot d \\
 W &= 20 \cdot 15 \\
 W &= 300 \text{ J}
 \end{aligned}$$

S1: The sketch helps me know what I am doing, what I have, list all the knowns [...] it helps me visualize it so I can make sense of what's going on [...] and then manipulate the equations separately.

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Results

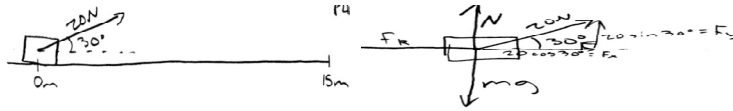
Profile: Mental Model Descriptors of Actions

	Symbolic	Graphical	Linguistic
Qualitative	Explain derived concepts for graph; describe equation		
Quantitative	Use equations; aware of graphical strategy	Use graph	Include diagram; use it in conjunction with equations

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Example: Mental model

Linguistic Task, Quantitative Solution



$$W_{\text{Total}} = W_y + W_x \quad W_y = (N + 20N \cdot \sin 30 - mg) \times 0$$

$$W_x = (F_x - F_R) \times \quad W_x = (20 \cdot \cos 30 - 22) \times (-4.68N)$$

S2: The diagrams help me visualize it, know what's going on, to put components, can't confuse sine and cosine [...] total work done is work done in y direction plus work done in x direction.

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Discussion

According to Cognitive Framework

Propositional Representation

- handle symbolic and visual representation **in isolation**
- seem to have **poor understanding** of concepts

Mental Model

- **link** structural and syntactic aspects of representation
- **interpret** and seem to **understand** the concepts

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Implications for Teaching

Promote mental model construction

Create...

- representation-rich learning environment and materials.
- forefront the role of visual representations.
- explicit exposure to various ways of handling problems with particular representations.

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Thank you

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