Intuitive vs. formal reasoning in introductory physics

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Motivation

Students tend to:

- perform poorly on unfamiliar problems, despite demonstrating conceptual understanding[1]
- apply intuitive reasoning to unfamiliar problems
- use the first available mental model ("gut reaction"), leading to incorrect answers

An understanding of why students resort to using intuition, despite having formal knowledge, would lend itself to developing tools to prompt students to use this formal knowledge more readily.

Theoretical framework

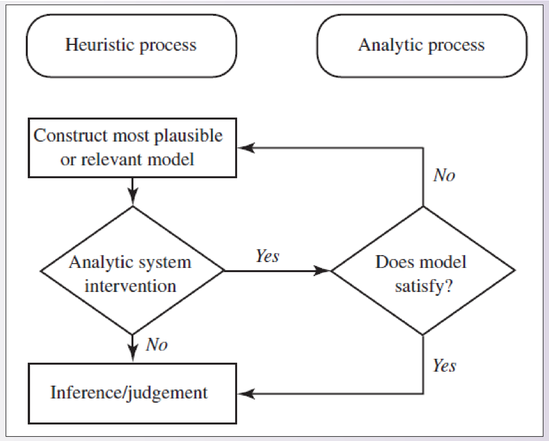

Fig. 1: The dual-process theory proposed by Evans[2].

Research question #1

Do metacognitive interventions engage the analytical system presented by the dual process theory?

Metacognitive intervention

What answer do you think people who applied intuitive thinking […] would give? Have you applied intuitive reasoning/knowledge or formal reasoning/knowledge? Explain.

Method 1: Metacognition

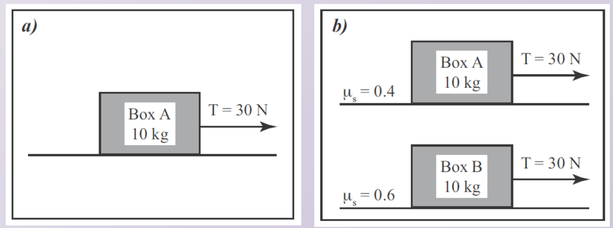

Fig. 2: Question sequence 1 (friction). All three blocks are at rest. Students were asked to compare the magnitude of the force applied to the force of friction.

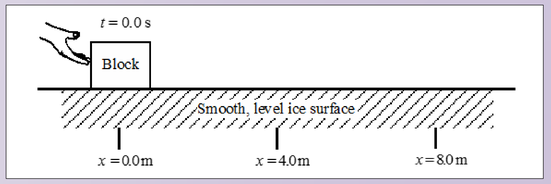

Fig. 3: Question sequence 2 (force). From 0m to 4m, a constant force is applied. From 4m to 8m, a constantly decreasing force is applied. Students were asked to describe the block's motion (speeding up, constant speed, or slowing down) for both distances.

For both sequences, the metacognitive intervention was given to half of the students. The other half received no such intervention.

Friction sequence, correct responses (N = 107):

- No intervention: (a) = 81%, (b) = 65%
- With intervention: (a) = 85%, (b) = 66%

Force sequence, correct responses (N = 82):

- No intervention: (a) = 73%, (b) = 56%
- With intervention: (a) = 80%, (b) = 68%

No statistically significant improvement was observed in either population.

Conclusions

There is no difference in student performance with or without metacognitive intervention.

Method 2: Eye tracking

Reasoning is investigated by combining two data streams:

- Heat maps generated by eye tracker during problem solving
- Verbal interviews following the problem session

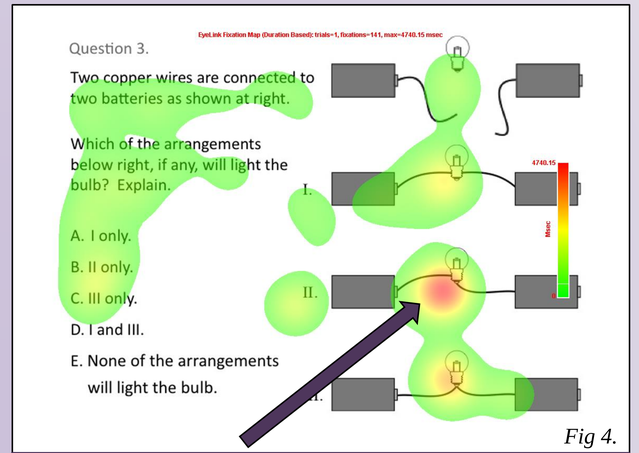

Fig 4.

"[…] when you're talking about a bulb, that means that the wires have to connect to […] the shaft part of it, and then also the little piece at the end."

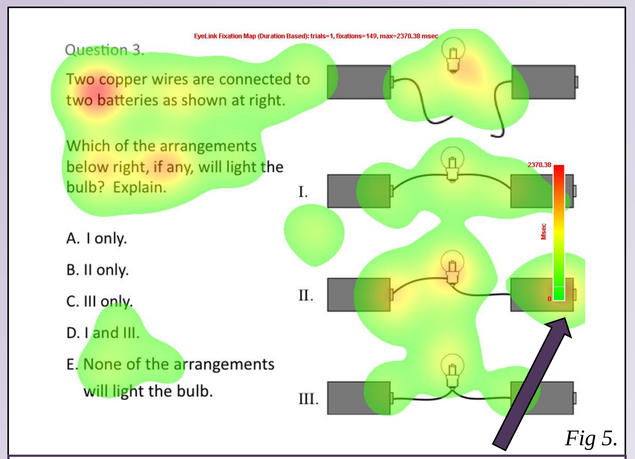

Fig 5.

"I thought that […] to light up the bulb these two batteries should be connected as well, cause it's not a circuit. It's not complete."

Research question #2

Are the data generated by the eye tracker consistent with the dual process theory framework?

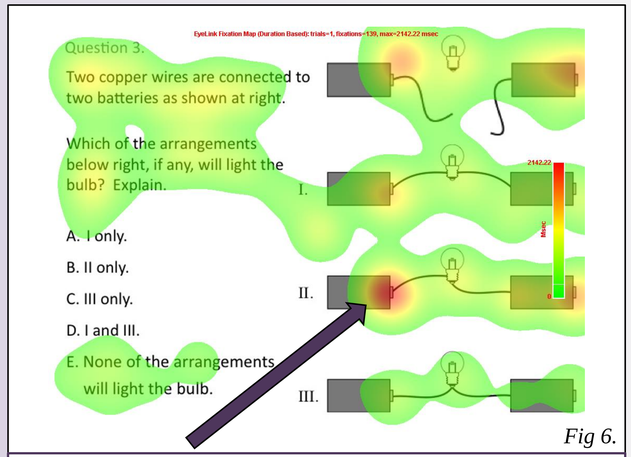

Fig 6.

"I actually took time to look at it and try and think of it […] like how you put a battery in a remote. […] I would think that the batteries would have to face each other."

Preliminary findings

Both verbal explanations and heat maps suggest that the first available mental model cues what the question is "about" for the individual, and guides their reasoning. In these cases:

Fig 4: connection to lightbulb
Fig 5: completeness of circuit
Fig 6: direction of batteries

Future directions

Build on the present findings to design and test different modes of metacognitive interventions

Identify strategies for engaging the analytical system more productively while solving physics problems

Replicate eye tracking methodology on a larger scale

References

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