Using fMRI to Compare Cerebral Activations between Novices and Experts in Science during a Task in Mechanics Involving a Common Misconception

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INTRODUCTION

- Students have erroneous and persistent conceptions about mechanics (Brown & Hammer, 2008). These conceptions are resistant to pedagogical interventions (Astolfi, Peterfalvi, & Vérin, 2006).
- Many researchers have studied conceptual change, but there is no consensus on the processes underlying conceptual change (diSessa, 2006) and there is also no consensual answer as to what happens to the initial conceptions of students after the completion of a conceptual change.
- Are these initial conceptions deleted, reorganized, replaced, integrated into a new, broader theory, or do they remain present, therefore coexisting with new scientific knowledge?

Hypothesis

- Recent studies, particularly in the field of electricity (Masson, 2012), point to the idea that the brain's mechanism of inhibition would play a role in learning science.
- Studies related to inhibition show activations in the anterior cingulate cortex and the prefrontal cortex (Bush et al., 1998; Houdé et al., 2001).

We hypothesize that experts will present stronger cerebral activations than novices in brain regions associated with inhibition when they have to answer questions involving the common conception in mechanics "a heavier ball falls faster than a lighter ball".

METHOD

- fMRI is used to see if inhibition networks play a role in learning mechanics.
- T2* images are obtained with a 3T Siemens TRIO TIM (12 channels, TR = 2.0 s, whole brain scanned)

Participants

Groups of participants differ in their education and conceptions about mechanics.

Novices (n = 19)	Experts (n = 10)
Right-handed	Right-handed
Male	Male
23.53 years old (SD = 2.8)	22.30 years old (SD = 2.4)
Baccalaureate students	Baccalaureate students
Humanities students	Physics students
Naive conceptions	Scientific conceptions

Task

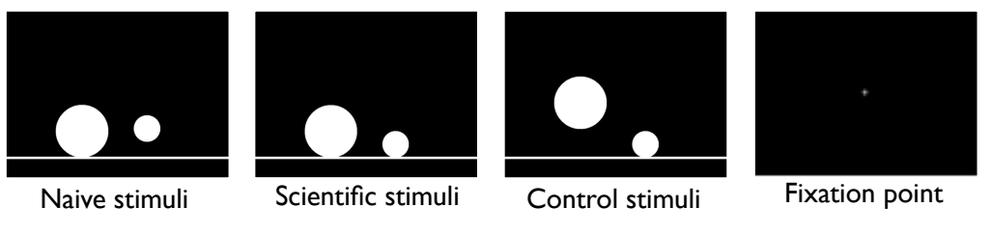

Figure 1. Types of stimuli used in the task. For each stimulus, participants must state if it is correct or incorrect. Stimuli are presented randomly in two equivalent runs. They are presented until the participant answers, but change after 3.5 s automatically if no answer is provided. Each stimulus is followed by a fixation period of 2.5 or 3.5 s.

RESULTS

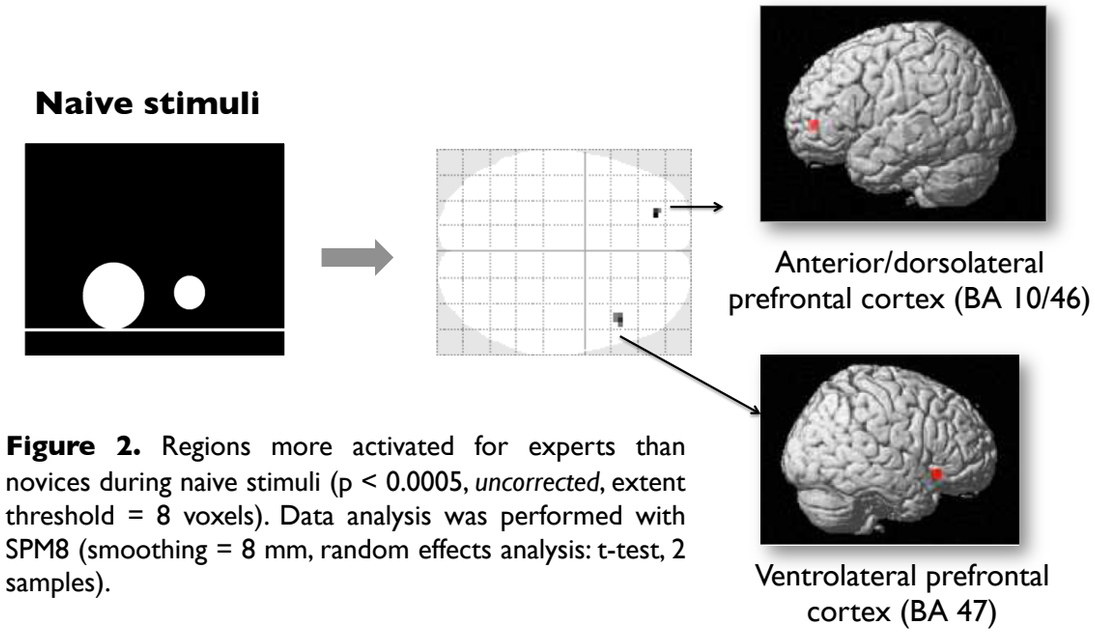

Figure 2. Regions more activated for experts than novices during naive stimuli ($p < 0.0005$, *uncorrected*, extent threshold = 8 voxels). Data analysis was performed with SPM8 (smoothing = 8 mm, random effects analysis: t-test, 2 samples).

- Significant differences of activation between novices and experts are observed in specific brain regions.

DISCUSSION

- Brain differences between novices and experts indicate that these two groups do not perform the same cognitive work when they evaluate naive stimuli.
- Experts show greater activations than novices in the anterior/dorsolateral prefrontal cortex (BA 10/46) and in the ventrolateral prefrontal cortex (BA 47).
- These brain regions are associated with inhibition (Monchi et al., 2001; Lie et al., 2006). It therefore seems that the ability to inhibit initial conceptions is related to scientific expertise in mechanics.
- This suggests that the preconceptions in mechanics have not been eradicated or transformed during learning: they would rather have remained present in the brain and experts would have learned to inhibit them to provide a scientifically correct answer.

CONCLUSION

- There is a difference in brain activations between subjects holding a greater conceptual understanding in mechanics (experts) and those with lower conceptual understanding (novices).
- This means that expertise in mechanics would be linked to a better ability to inhibit initial conceptions.
- These results in mechanics support previous findings in electricity (Masson, 2012). Inhibition could therefore be related to expertise in several scientific disciplines.
- Further studies will provide a better understanding and characterization of the role of inhibition in science learning.
- How can we help students learn to inhibit their initial conceptions?

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