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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 yet (diSessa, 2006, 2008).
- One way to investigate conceptual change is to compare novices and experts, assuming that the experts have undergone a conceptual change. (Dunbar, Fugelsang & Stein, 2007; Pettito & Dunbar, 2004).

Hypothesis

A previous study suggests that inhibition might play a role in conceptual change in mechanics (Dunbar, Fugelsang, & Stein, 2007)

Another study has also indicated that experts in science were using brain regions linked to inhibition when answering correctly to questions in electricity involving misconceptions (Masson, 2012).

Studies related to inhibition show activations in the anterior cingulate cortex, the prefrontal cortex and the medial frontal cortex (Bush et al., 1998; Houdé et al., 2001).

Are the cerebral regions of inhibition associated to expertise in mechanics?

Brain areas related to inhibition will be more activated for experts than for novices, suggesting that inhibition mechanisms are involved in mechanics expertise.

Method

- IRMf is used to see if inhibition networks play a role in expertise in 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

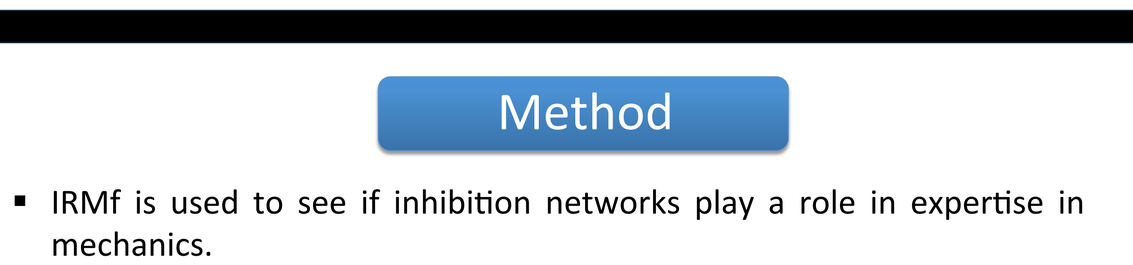
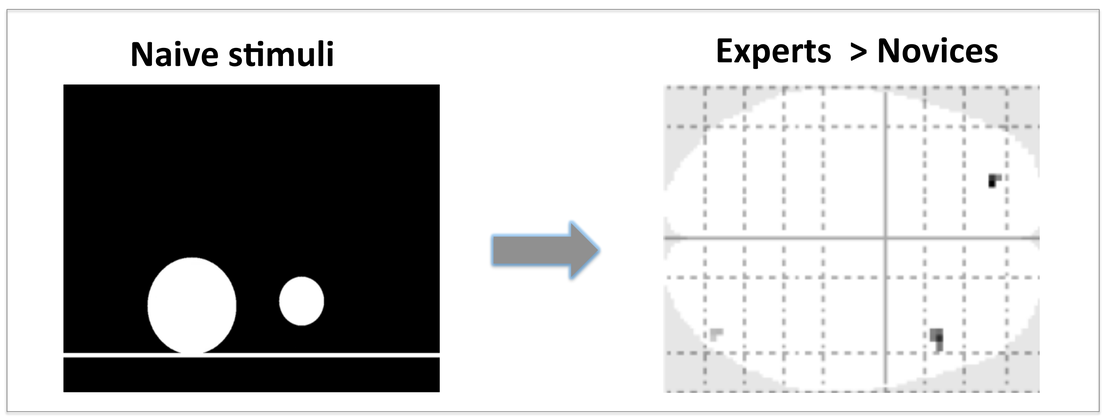


Figure 2. Types of stimuli used to investigate expertise in mechanics. For each stimulus, participants must say if it is correct or incorrect. Stimuli are presented randomly in two equivalent runs. They are presented until participant answers (but after 3,5 s it changes automatically if no answer is provided). Each stimulus is followed by a fixation period of 2,5 or 3,5 s. Fixation point is also used as a type of stimuli and, for this purpose, it is presented for 6,0 s.

Results



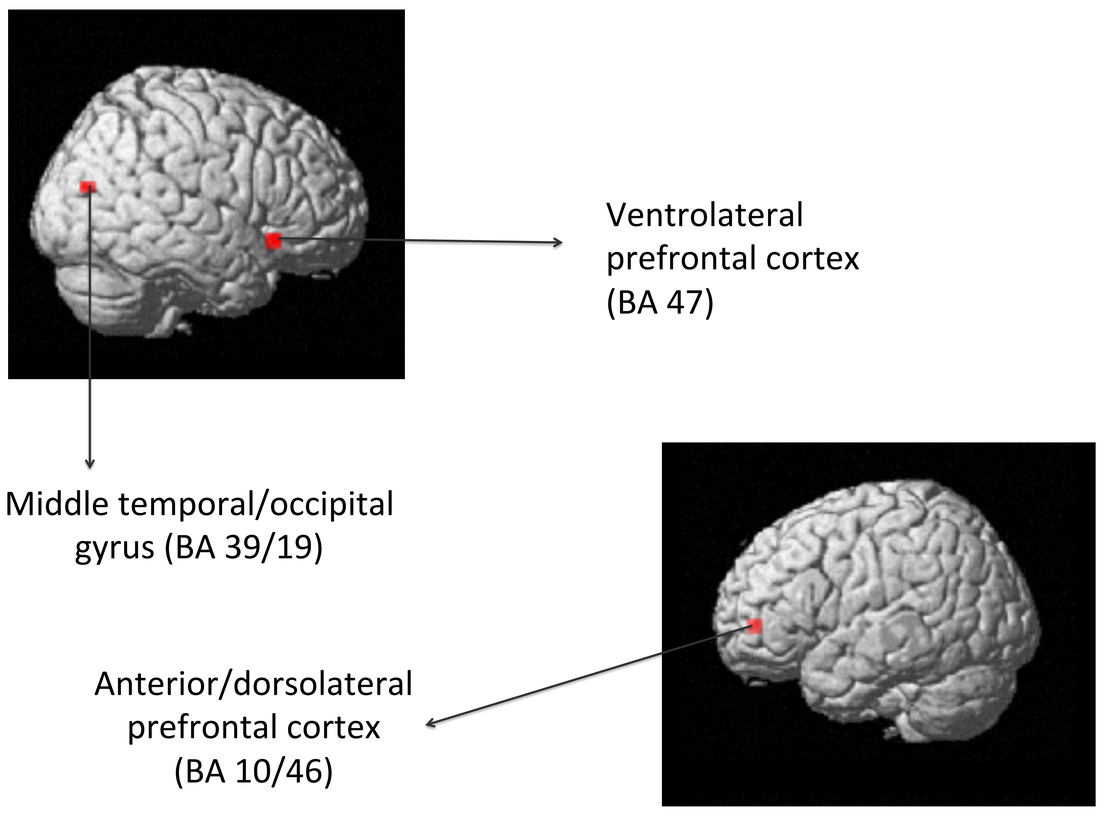


Figure 3. Regions more activated for experts during naive stimuli ($p < 0{,}001$ *uncorrected*, extent threshold = 0 voxels). Data analysis was performed with SPM8 (smoothing = 8 mm, random effects analysis: t-test, 2 samples).

Discussion

- Significant differences of activation between novices and experts are observed in specific brain regions.
- Experts show greater activations than novices in the ventrolateral prefrontal cortex, the anterior/dorsolateral prefrontal cortex and the middle temporal/occipital gyrus.
- These activations suggest that experts rely more on executive functions (BA10/46 and BA47) and spatio-visual processes (BA19).
- Experts, therefore, activate regions that are associated with inhibition, such as the ventrolateral and dorsolateral cortices (Bush et al., 1998, Menon et al., 2001), but, since the anterior cingular cortex is not activated, it is not possible to tell with certainty if inhibition is involved in mechanics expertise for this task.

Conclusion

- Experts seem to rely more on executive functions and spatio-visual processes than novices when answering to questions involving a misconception in mechanics.
- Further studies will provide a better understanding and characterization of expertise in mechanics.