Expertise in Electric Circuits Relies on Brain Areas Involved in Inhibition

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Introduction

- Students have erroneous and persistent conceptions about electric circuits (Çepni & Keles, 2006; Periago & Bohigas, 2005).
- Conceptual change is a widely explored domain of research in science education since the 80's, but there is no consensus on the processes underlying conceptual change yet (diSessa, 2006, 2008).
- Discovering new information using neuroimaging can provide useful insights for understanding conceptual change.

What are the brain-based mechanisms underlying conceptual change in electricity?

Hypothesis

- Inhibition might play a central role in certain types of learning (Houdé, 2004) – for instance, in situations where learners must overcome spontaneous and inappropriate strategies or answers.
- One study suggests that inhibition might play a role in conceptual change in mechanics (Dunbar, Fugelsang, & Stein, 2007)
- Studies related to inhibition show activations in the anterior cingulate cortex, the prefrontal cortex and the medial frontal cortex (e.g. Bush *et al.,* 1998; Houdé et al., 2001, Menon *et al.*, 2001).

If inhibition plays a role in conceptual change, brain areas related to inhibition will be more activated for experts than for novices.

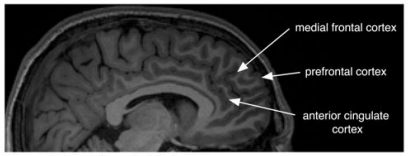

Figure 1. Brain regions related to inhibition.

Method

- fMRI is used to see if inhibition networks play a role in conceptual change.
- 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 electricity.

Novices	Experts
12 participants	11 participants
22,9 years old (SD = 3,5)	22,1 years old (SD = 2,3)
right-handed	right-handed
male	male
baccalaureate students	baccalaureate students
humanities students	physics students
naive conceptions (> 90 %)	scientific conceptions (> 90 %)

Task

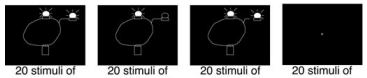

Figure 2. Types of stimuli used to investigate conceptual change in electricity. For each stimulus, participants must say if the circuit is correct or incorrect. Stimuli are presented randomly in two equivalent runs. Circuits are presented until participant answers (but after 3,5 s it changes automatically if no answer is provided) 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.

Analysis

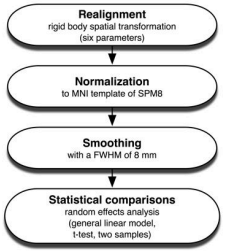

Figure 3. Overview of the data analysis performed with SPM8.

Results

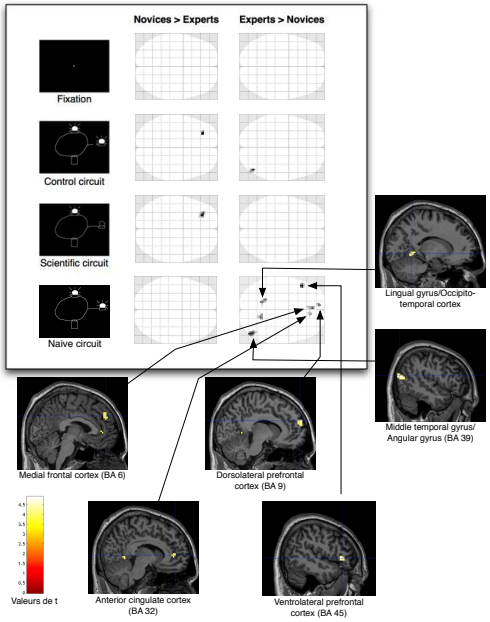

Figure 4. Regions more activated for novices and for experts for each type of electric circuits ($p < 0{,}001$ uncorrected, min. 10 voxels).

- There are only a few differences between experts and novices when they evaluate scientific circuits and control circuits. Novices show greater activations than experts in the left dorsolateral prefrontal cortex when they evaluate both scientific and control circuits. Experts show higher activations than novices in the right angular gyrus when they evaluate control circuits.
- But when they evaluate naive circuits, experts show greater activations than novices in many regions such as the anterior cingulate cortex, the medial frontal gyrus and regions of the prefrontal cortex (see figure 4).

Discussion

- Experts need more cerebral resources to evaluate naive circuits, although one could think it is easier for expert to answer than for novices.
- Experts seem to rely primarily on inhibition networks when they evaluate naive circuits.
- This could mean that experts have not change their naive conception (one wire can light a bulb) and have to inhibit it to answer correctly.
- Data do not support conceptual change models postulating that conceptions are erased or transformed into something else after conceptual change.
- Data are compatible with conceptual change models that postulate that conceptions are build with cognitive resources that still exist after conceptual change, or with models that postulate a cohabitation of conceptions.

Conclusion

- When they evaluate naive circuits, experts show more activations in brain areas related to inhibition.
- Thus, student's conceptions might not be transformed into something else after conceptual change but rather might be inhibited.
- Future studies: a better characterization of expertise in electricity might allow comparison and evaluation of science teaching methods.

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