Mieux connaître le cerveau peut-il vraiment nous aider à mieux enseigner?

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Capsules Savoirs - Centre de recherche interuniversitaire
sur la formation et la profession enseignante
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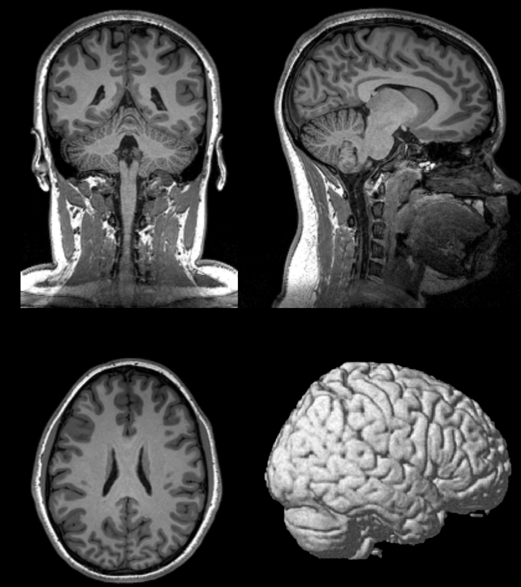


Pertinent selon certains

- OCDE (2007, p. 18) : « La neuroscience de l'éducation débouche sur des connaissances précieuses et neuves, qui permettent d'informer politiques et pratiques éducatives »
- Royal Society (2011, p. 20) : « Training and continued professional development should include a component of neuroscience relevant to educational issues »
- Havard : programme de maîtrise en neuroéducation depuis 2004
- Association canadienne d'éducation : prix Clifford 2013 accordé à un chercheur en neuroéducation

Impertinent selon d'autres

- Bruer (1997, p. 4): « Educational applications of brain science may come eventually, but as of now neuroscience has little to offer teachers in terms of informing classroom practice. »
- Neuromythes :
  1. styles d'apprentissage (Pashler et al., 2008)
  2. cerveau gauche / cerveau droit (Nielsen et al., 2013)
  3. Brain Gym (Spaulding et al., 2010)
  4. Etc.
- Livres s'adressant aux enseignants

D'où la question

Mieux connaître le cerveau peut-il vraiment nous aider à mieux enseigner?

Ce que la neuroéducation n'est pas

- Approche qui peut se passer d'autres approches
  - Approche qui s'oppose aux autres approches
  - Approche meilleure que les autres
- Approche purement déterministe
- Approche réductionniste qui ne tient pas compte du contexte
- Approche dont les finalités sont les mêmes que celles de la neuroscience
- Approche qui peut prescrire exactement aux enseignants quoi faire

Ce que la neuroéducation est

- Une approche qui étudie les mécanismes cérébraux liés aux apprentissages scolaires et à l'enseignement dans le but de mieux comprendre et parfois d'apporter des pistes de solution à certaines problématiques éducatives (Masson, 2012)
- Une approche qui se situe à un niveau d'analyse difficilement inaccessible auparavant (Geake & Cooper, 2003; Pettito & Dunbar, 2004)
- Une approche qui permet d'accéder à une nouvelle information : l'activité cérébrale (Henson, 2005)
- Une approche qui permet parfois de vérifier des hypothèses et de stimuler la formulation d'hypothèses inédites (Byrnes & Fox, 1998; Geake & Cooper, 2003)
- Une approche qui permet de trianguler les résultats.
- Une approche qui permet de comprendre pourquoi, au niveau cérébral, certaines approches pédagogiques ont plus d'impact.

Trois grandes découvertes

- Apprendre modifie la structure du cerveau.
- L'architecture du cerveau influence l'apprentissage.
- L'enseignement influence le développement du cerveau.

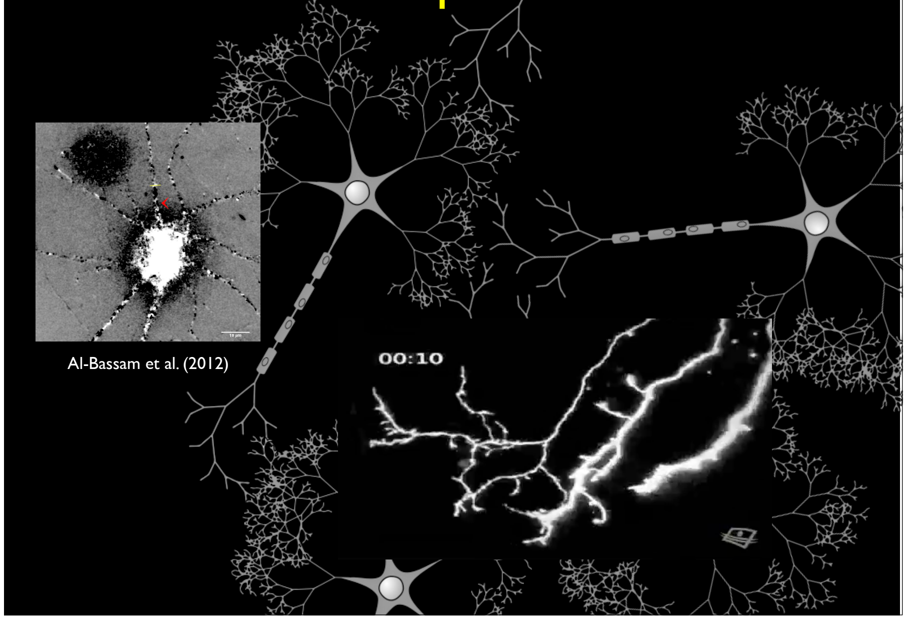
Architecture cérébrale = alliée + adversaire

Outils = neuroplasticité + recyclage neuronal + inhibition

1. Neuroplasticité

La neuroplasticité désigne la capacité du cerveau à changer ses connexions neuronales grâce à l'apprentissage.

Neuroplasticité



Al-Bassam et al. (2012)

Les neurones qui s'activent ensemble
se connectent ensemble.

Comment favoriser la neuroplasticité?

Recommandation pédagogique : réactivation neuronale

Les neurones doivent s'activer à de nombreuses reprises.

- Proposer des tâches qui impliquent de mobiliser des savoirs spécifiques.
- Questionner, faire enseigner, interagir, etc.
- Tester : exercices, évaluations formatives, mini-tests, examen, etc.
- Montrer comment étudier : en se posant des questions à soi-même.
- ...

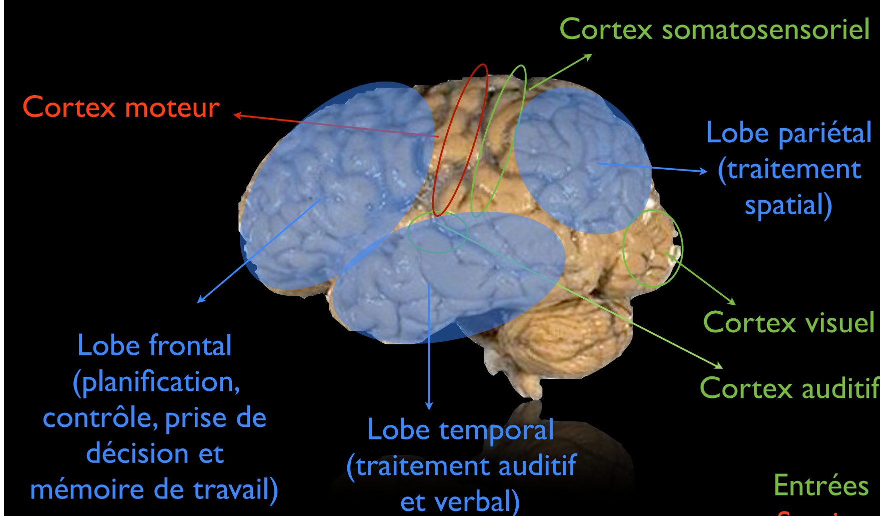
Recommandation pédagogique : espacement

Il faut espacer les périodes d'apprentissage.

- Lors de la planification, répartir le temps alloué à un apprentissage (4 X 30minutes plutôt que 1 X 2heures).
- Éviter de regrouper les périodes d'enseignement allouées à un sujet donné.
- Revenir sur les contenus déjà appris.
- Donner des devoirs sur des contenus abordés.
- Montrer comment étudier : espacer les périodes d'études.
- ...

2. Recyclage neuronal

Le recyclage neuronal est le processus par lequel le cerveau modifie une région cérébrale pour changer sa fonction.



Entrées
Sorties
Traitement de l'information

Modèle contemporain simplifié (2006)

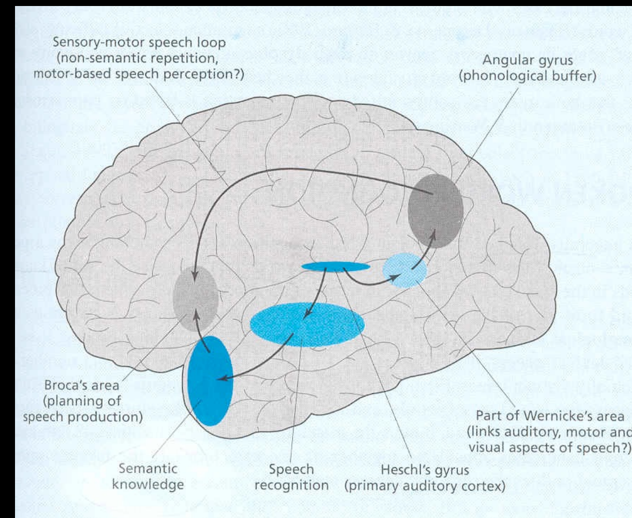


Figure tirée de Ward (2006, p. 211)

Lecture

Tarkiainen, Cornelissen, & Salmelin (2002)

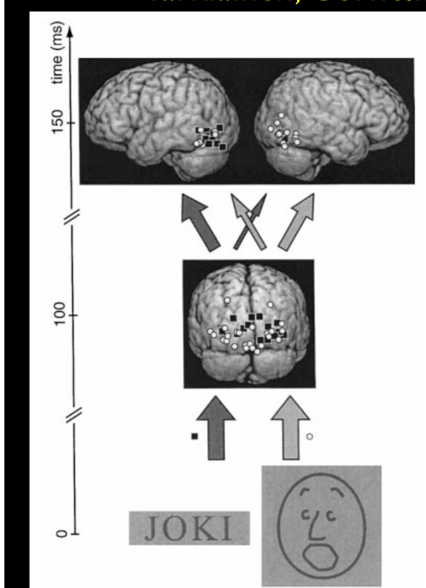


Fig. 7 Early (<200 ms) processing of face and letter-string information consists of at least two distinct stages. The middle part of the figure illustrates the first stage (Type I), which takes place in the occipital cortex ~100 ms after image onset. This activation does not differ between face and letter-string processing. The locations of Type I sources evoked by letter-strings are marked with black squares and the locations of Type I sources activated by faces with white circles. The second activation pattern ~150 ms after image onset is specific to the stimulus-type (top part of the figure), with strong lateralization to the left hemisphere for letter-strings (black squares) and slight right-hemisphere preponderance for faces (white circles). See Discussion for details. Sources are gathered from all 10 subjects and their locations are shown on MRI surface renderings of the standard brain geometry.

Shaywitz *et al.* (2007)

Régions frontales diminuent

Région occipito-temporal gauche augmente

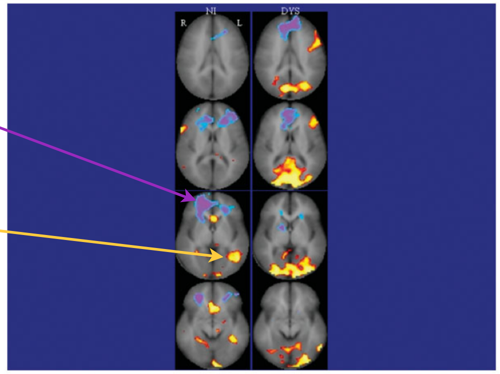
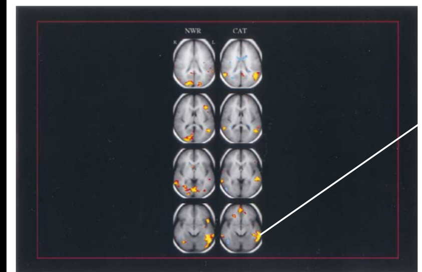


Fig 2. Correlation maps between age and activation for nonimpaired (NI) and dyslexic (DYS) readers during a nonword rhyming (NWR) task. For each group of readers, a correlation with age was calculated using general linear model (GLM) with skill (in-magnet accuracy) included as a covariate. Areas in yellow and red indicate a positive correlation between age and activation (threshold, $p < 0.05$*). Brain regions in blue and purple indicate a negative correlation between age and activation (threshold,* $p < 0.05$*). The four rows of images from top to bottom correspond to* $z = +23, +14, +5$*, and* -5 *in Talairach space.*[32] *Age-related* increases *in NI readers are seen primarily in the left anterior lateral occipitotemporal region, and in DYS readers in the left inferior frontal gyrus and left and right posterior medial occipitotemporal regions. Age-related* decreases *in NI readers are seen mainly in the left and right superior and middle frontal gyri, and in DYS readers in the bilateral superior frontal gyri and anterior cingulate gyrus.*

7 à 18 ans

Shaywitz *et al.* (2002)



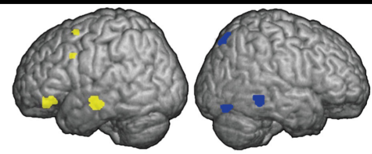
Région occipito-temporale gauche

Figure 3. Correlation map between reading skill as measured by the Word Attack reading test (Woodcock and Johnson 1989) performed out of magnet and nonword rhyme (NWR) and semantic category CAT tasks performed during functional magnetic resonance imaging for the group of 144 children. At each voxel, a Pearson correlation coefficient (r) was calculated with age included as a covariate; a normal distribution test was used (Hays 1988). Areas in yellow-red show a positive correlation of in-magnet tasks with the out-of-magnet reading test (threshold, $p < .01$). The four rows of images from top to bottom correspond to $Z = +23, +14, +5$ and -5 of Talairach atlas. Strong correlation was found in the inferior aspect of the temporal occipital region (fourth row), in the more superior aspect of the temporal occipital regions (second and third rows), and in the parietal regions (top row). CAT, semantic category.

Notez que la droite du cerveau sur cette figure représente l'hémisphère gauche.

Régions corrélées avec la performance en lecture

Turkelbaud *et al.* (2003)



	Brodmann area	Volume (mm³)	Cluster r	Peak Z	x	y	z
Positive							
Left							
Middle temporal gyrus	21	1,168	0.72	5.47	–51	–12	–11
Inferior frontal gyrus	47	1,008	0.66	4.31	–51	38	–17
				4.16	–46	32	–12
Superior frontal gyrus	6	240	0.60	4.13	–20	10	51
Cingulate gyrus	31	456	0.58	3.98	–2	–45	28
Inferior frontal sulcus	44/9	264	0.60	3.85	–34	13	27
Negative							
Right							
Inferior temporal sulcus	21/37	416	–0.64	–4.69	65	–39	–10
Precuneus	7	376	–0.59	–4.02	8	–73	48
Fusiform gyrus	19	264	–0.59	–4.00	48	–74	–13

Figure 5 Development of the neural basis of word processing. Developmental changes were assessed by correlation between mean-difference images and a reading composite score (raw Woodcock-Johnson III Letter-Word ID + Word Attack + Gray Oral Reading Test III revised passage score). Positive correlations between activity and reading ability appear in yellow; negative correlations appear in blue. The same pattern, with somewhat lower significance levels, emerged when activity was regressed with age instead of reading ability. Cluster r is the correlation coefficient between the mean BOLD activity in the region and the reading composite score. Peak Z is the maximum Z-score within the region. Coordinates of this maximum Z-score are based on the stereotactic system of Talairach and Tournoux[49]. Coordinates are relative to the anterior commisure in the interaural (x), anterior-posterior (y) and superior-inferior (z) directions.

Yoncheva *et al.* (2010)

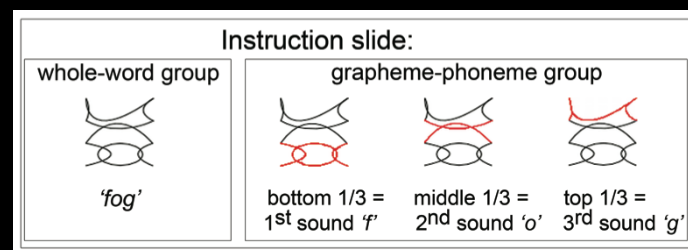


FIGURE 1 Manipulating attentional focus during training in artificial orthography. Participants were trained in either the whole-word condition or in the phoneme-grapheme condition. Training was identical for both groups (exactly the same visual characters and auditory words were presented), except for the instructional slide at the onset of training, which prescribed the use of one of two learning strategies. The grapheme-phoneme group was focused on linking the hidden letters with sounds within words, whereas the whole-word group was asked to associate whole visual characters with entire auditory words. (Figure is available in color online)

Yoncheva *et al.* (2010)

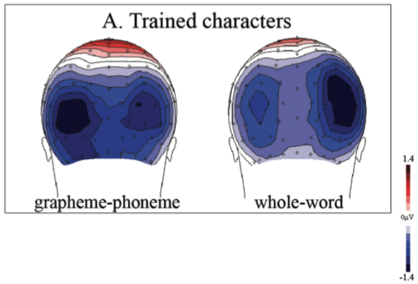
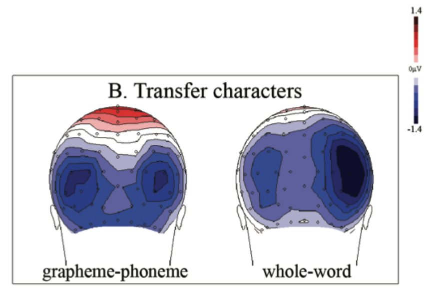


FIGURE 3 Topographic maps of the N170 ERP in response to (a) trained and (b) transfer characters in the reading verification task. The grapheme-phoneme group exhibits a predominantly left-lateralized topography over occipito-temporal regions relative to the right-lateralized topography of the whole-word group. (Figure is available in color online)

Yoncheva *et al.* (2010)



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Recommandations pédagogiques

- Travailler la reconnaissance des lettres en insistant sur les aspects de symétrie.
- Préconiser une approche syllabique d'enseignement de la lecture.
- Travailler à l'automatisation des étapes de la lecture (Deheane, 2007, p. 290).
- Enseigner de façon explicite : lettres forment des graphèmes, qui correspondent à des phonèmes qui forment des mots (Dehaene, p. 302).
- Rejeter l'approche globale?

Calcul

3. Inhibition cérébrale

L'inhibition est la capacité de contrôler ou bloquer nos intuitions, nos habitudes ou nos stratégies spontanées.

Régions cérébrales liées à l'inhibition

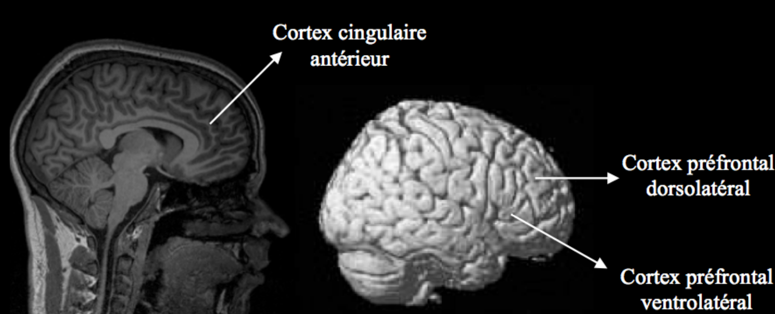
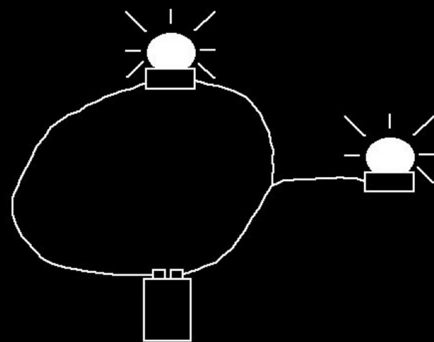


Figure tirée de Brault Foisy (2013)

En sciences

« Un seul fil est suffisant
pour allumer une ampoule. »



Masson et al. (2014)

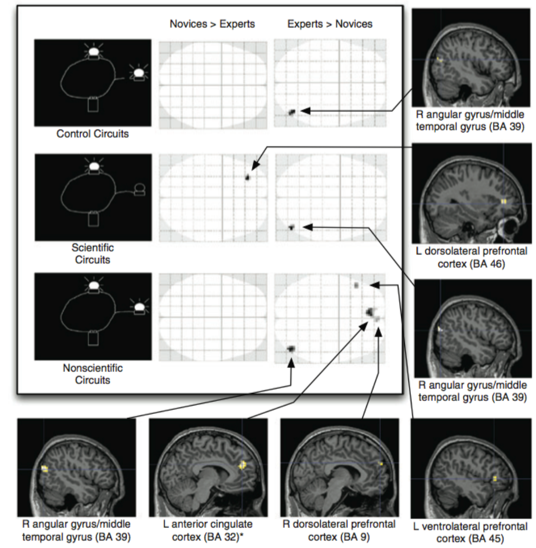
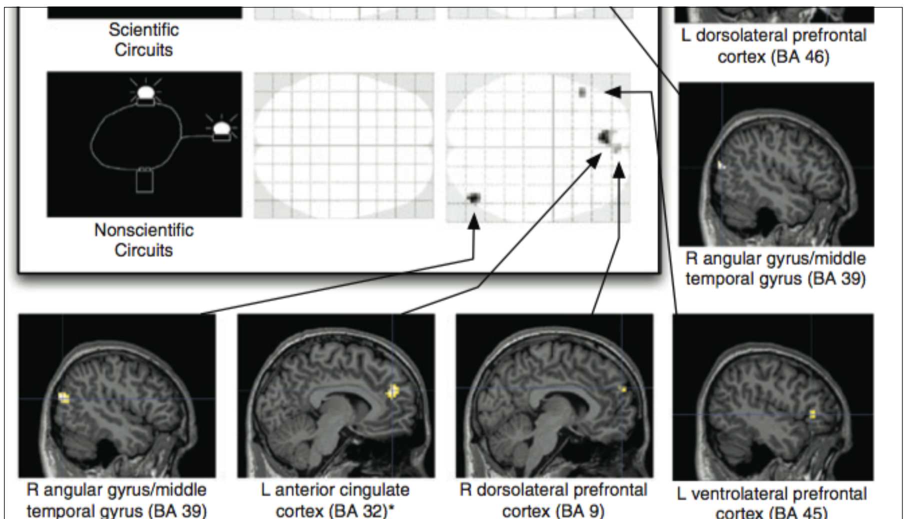


Fig. 2. Brain areas significantly more activated in experts and novices for each type of electric circuit compared to rest periods of visual fixation. ($p < .0005$, uncorrected, minimum 10 voxels, L = left; LR = left and right; R = right). *$p < .05$ FWE-corrected.



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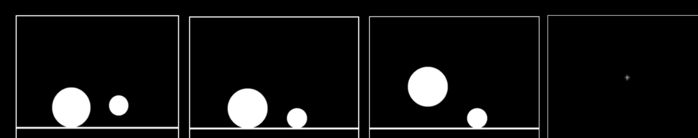
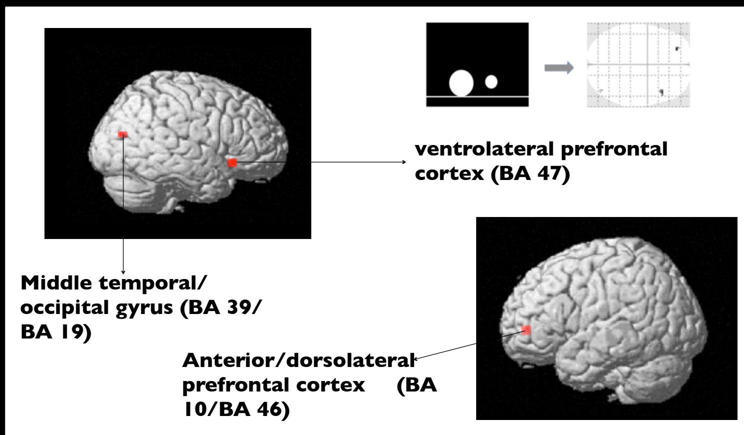
Brault Foisy, Masson, Potvin & Riopel (en préparation)

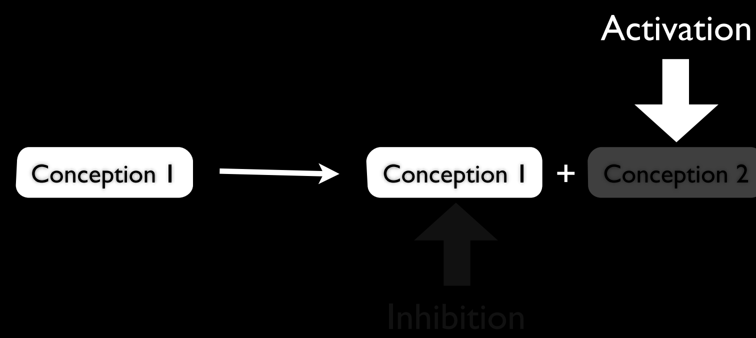


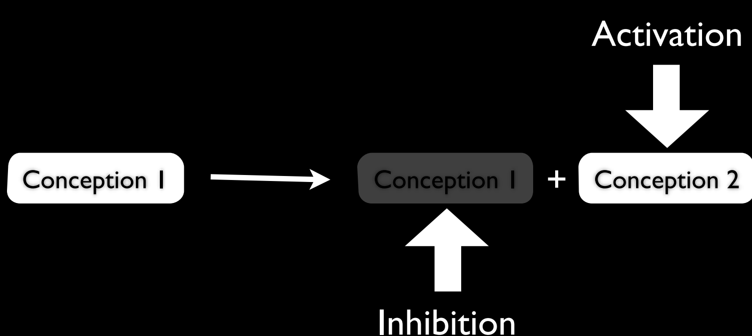
Condition non-scientifique	Condition scientifique	Condition contrôle	Repos (point de fixation)

Brault Foisy, Masson, Potvin & Riopel (en préparation)

Experts > Novices







En logique

Houdé et al. (2000)

Alertes émotives +
identification des réponses
qui sont des pièges.

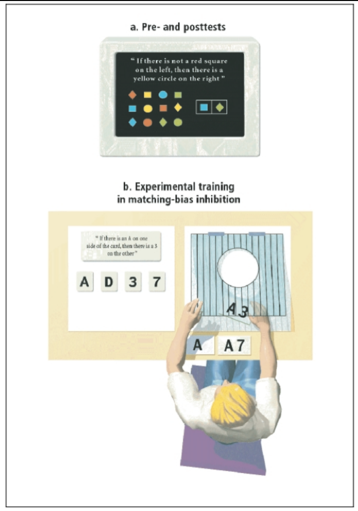
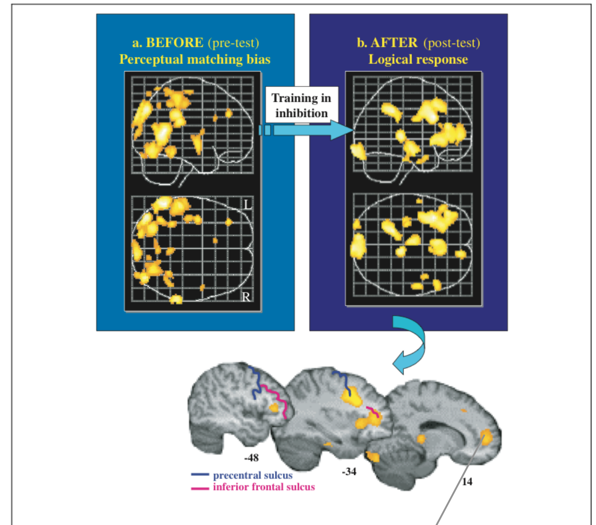


Figure 1. (a) Pretest (PET1) and posttest (PET2) materials on the conditional rule falsification task. (b) Materials used for experimental training in matching-bias inhibition (between PET1 and PET2). The first board was used for the card selection task. The second board depicts the executive process (inhibition, shown as hatching) required for correct task performance. (See Methods.)

Houdé et al. (2000)

Figure 2. Lateral and superior projections of statistical parametric z maps showing brain regions with increased cerebral blood flow (rCBF) during (a) the conditional rule falsification task when subjects were biased by perceptual matching (pretest) and (b) after the same subjects had been trained to inhibit the perceptual matching bias, i.e., to respond logically (posttest). Z maps were generated using SPM96 software by contrasting the pretest and posttest rCBF maps with a 3.09 z threshold ($p < 0.001$) (see Tables 1 and 2 for a detailed anatomical and statistical description). (b, bottom) Clusters of activation, whose anatomical localization, coordinates, and significance level are given in Table 2, were superimposed on selected sagittal slices of the MNI brain template. Each sagittal slice is labeled with its stereotactic x coordinate in millimeters: −48, −34, and 14.



Cortex cingulaire antérieur

Houdé et al. (2001)

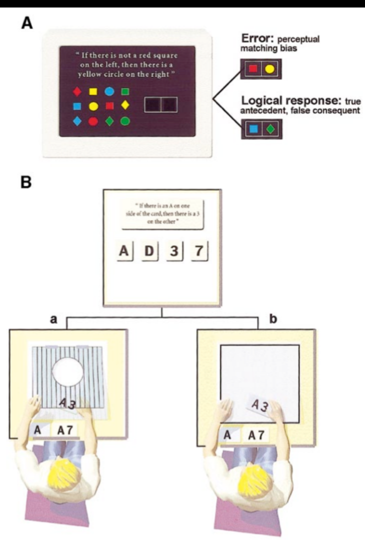
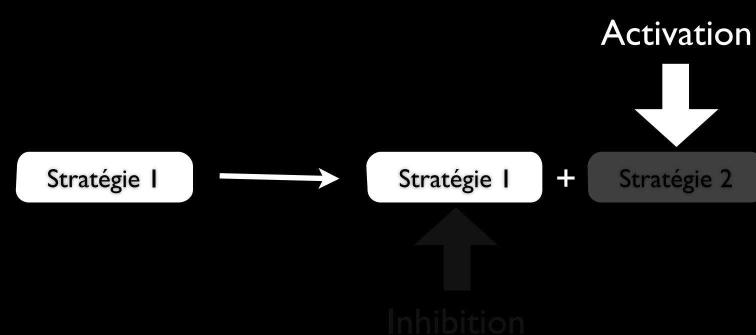
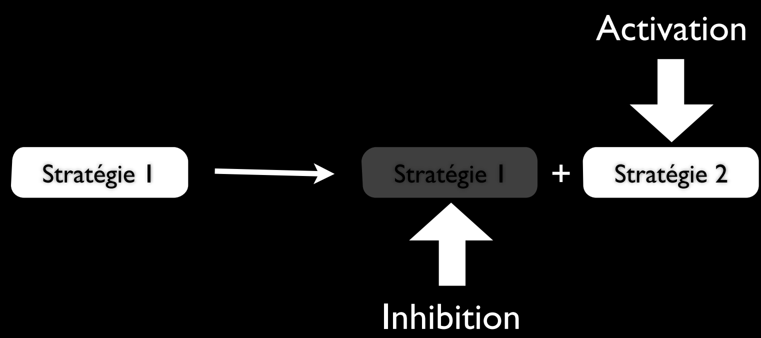


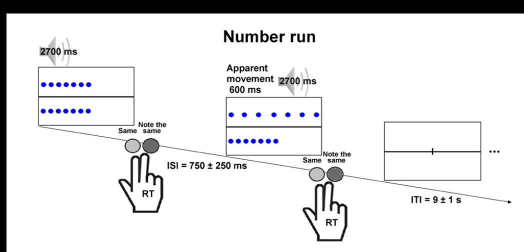
FIG. 1. Experimental design. (A) Pretest (PET 1) and posttest (PET 2) materials on the rule falsification task. (B) (a) Logicoemotional training in matching-bias inhibition; (b) training in logic only.





En mathématiques

Houdé et al. (2012)



Houdé et al. (2012)

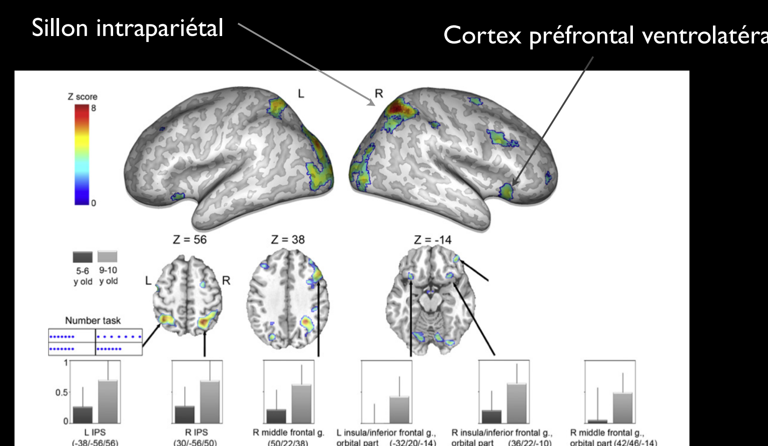


Fig. 4. 3D rendering of areas activated more in successful 9- and 10-year-olds (conservers) compared with unsuccessful 5- and 6-year-olds (nonconservers) during the Number task. Each plot represents the mean bold signal in the pointed cluster. L, left; R, right; frontal g., frontal gyrus.

9-10 ans (bonnes réponses) > 5-6 ans (mauvaises réponses)

ZDM Mathematics Education
DOI 10.1007/s11858-010-0251-z

ORIGINAL ARTICLE

Overcoming intuitive interference in mathematics: insights from behavioral, brain imaging and intervention studies

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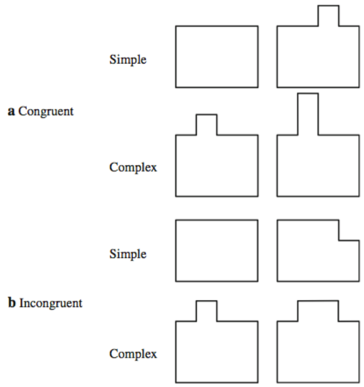

Fig. 2 Examples of complex and simple, congruent and incongruent trials

Intuition spontanée :
Si l'aire est plus grande,
le périmètre est aussi plus grand.

ZDM Mathematics Education
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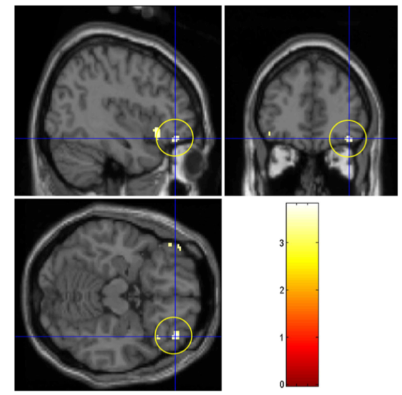
Fig. 5 Right prefrontal region (40, 42, −16) showing enhanced activity associated with overcoming intuitive interference (correct incongruent vs. correct congruent)



Il faut inhiber
son intuition.

Concernant l'inhibition…

- Les erreurs persistantes semblent basées sur des réseaux de neurones solidement établis.
- Les intuitions spontanées liées aux erreurs persistantes ne disparaissent peut-être jamais du cerveau des élèves.
- Apprendre, ce n'est pas juste construire de nouvelles connaissances/compétences.
- Apprendre, c'est parfois apprendre à inhiber ses connaissances antérieures.

Recommandations pédagogiques

- Développer l'inhibition par l'exercice physique.
- Développer l'inhibition par l'apprentissage d'une langue seconde.
- Développer l'inhibition en jouant à des jeux de contrôle (ex. « Jean dit… », Go/No-go, etc.).
- Prévenir les élèves de l'existence de pièges.
- Apprendre aux élèves à identifier les réponses qui sont des pièges.
- Allers et retours constants entre intuitions spontanées et savoirs scolaires.

Conclusion

Synthèse

- Il faut se méfier des neuromythes!
- Neuroplasticité : réactiver et espacer
- L'architecture du cerveau influence l'apprentissage :
  - ★ Recyclage neuronal (lecture et calcul)
  - ★ Inhibition (erreurs persistantes)
- L'enseignement adapté à l'architecture cérébrale
- Un appui au constructivisme?

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