Cognitive Neuroscience and Education: The Brain is No Longer a Black Box

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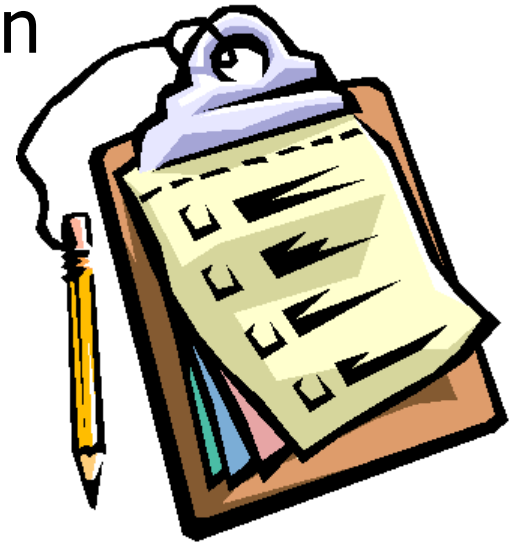
Agenda

- Motivation
- Definition of Cognitive Neuroscience
- Methods Used (EEG, fMRI)
- Cognitive Neuroscience Findings on
  - Mathematics
  - Emotion
  - Multimedia
  - Special Education
- New research opportunities
- Summary



Motivation

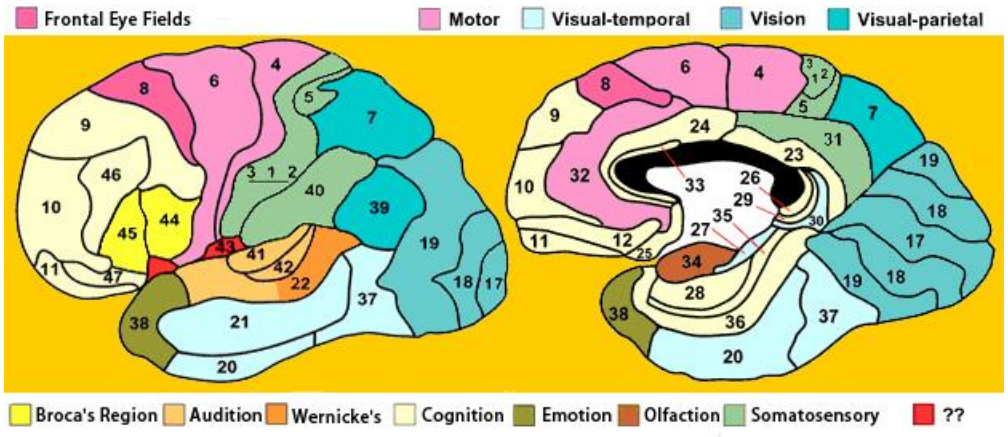
- To contribute to instructional technology, research based-on solid theory needed
- With technological improvements, incredible progress in neuroscience
- New opportunities to researchers
- Explain the mind works
- Create more effective learning

Mind as black box

- A metaphor by behaviorists
- cannot know how mind works
- exclude unobservable processes from the scientific field studies

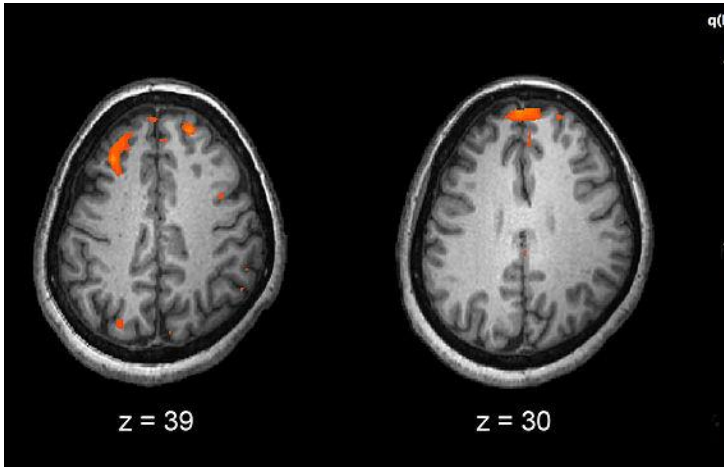
Cognitive neuroscience

- New methods (fMRI, EEG, PET) enable study of mental processes
- Study neural substrates (functional units) of cognitive processes in vivo (within the living)
- Localization view: cognitive functions located in specific brain areas (modules)
- Ex: FFA for face processing



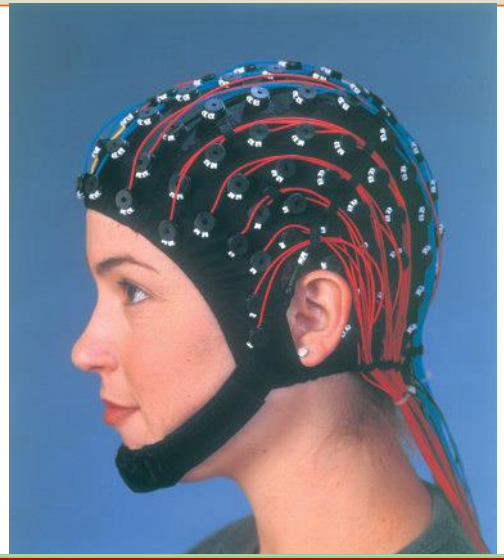
fMRI

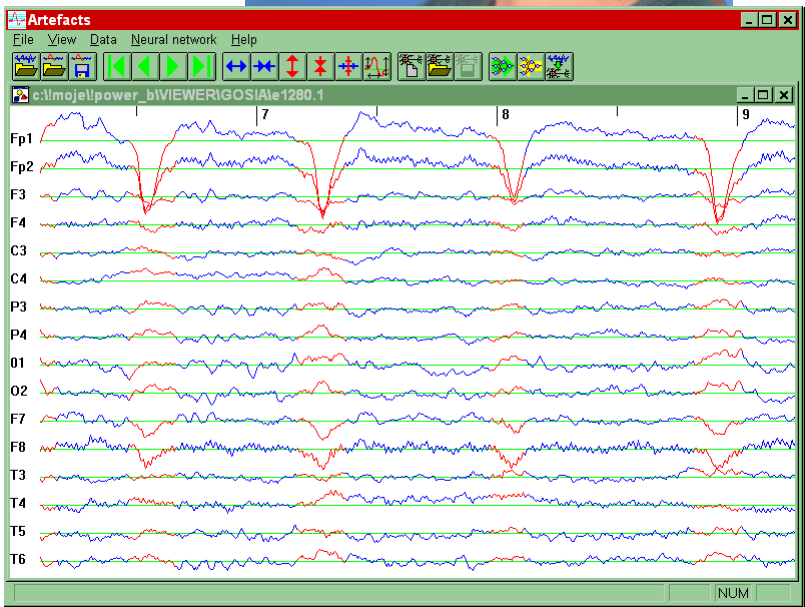
- Active area consumes more oxygen
- Difference in magnetic properties of oxygenated and deoxygenated hemoglobin
- High spatial resolution
- Low time resolution



EEG

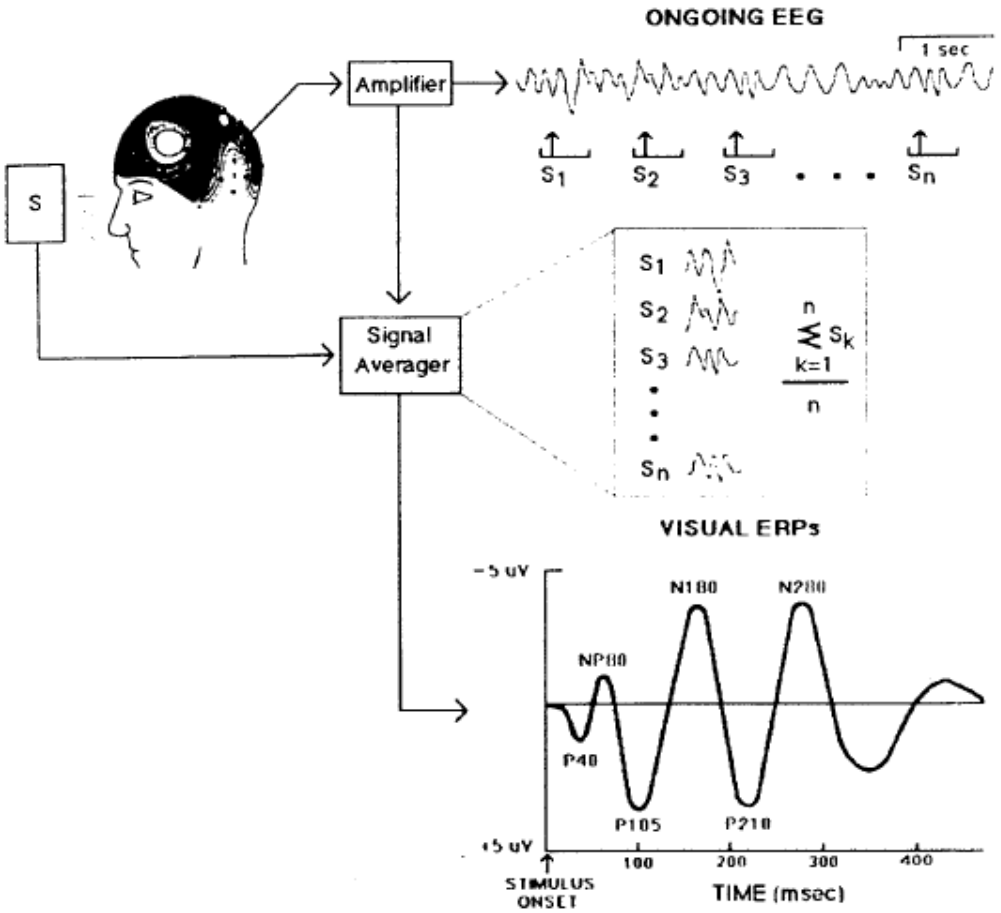
- Electroencephalography
- Electrodes on scalp
- Records electrical activity
- Needs amplifier
- High time resolution
- Low spatial resolution
- Low cost





Challenges for Educational Research

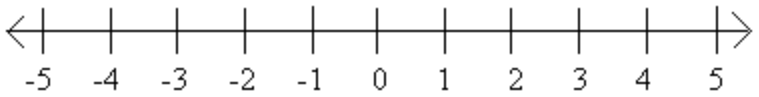
- Signal-to-noise ratio is small
- Repetitive tasks
- Not very suitable for educational studies



Effect of education & environment

- London taxi drivers having bigger hippocampus (related with navigation and storing spatial representations). (Maguere et al., 2000)
- Increased auditory cortical representation in expert musicians (Pantev et al., 1998)
- Use of areas for spoken language (auditory info) to represent sign language (visual info) in deaf people
- Recruiting of visual brain areas for Braille reading (requires tactile, not visual analysis) in blind people

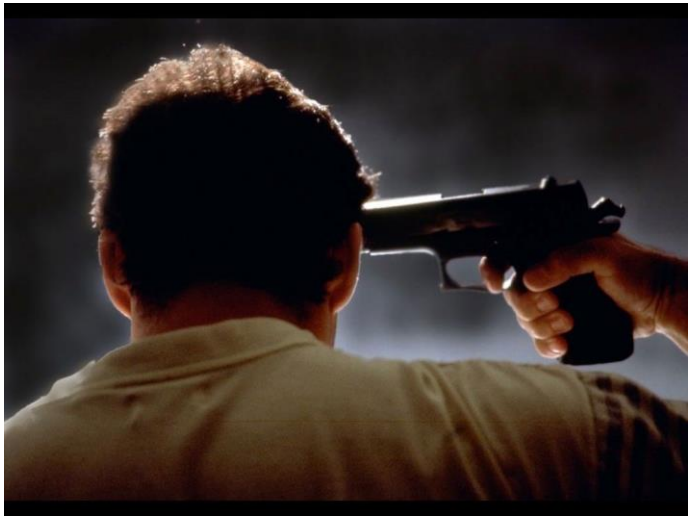
Mathematics



- Dependence of arithmetic operations on mental number line (Goshawi, 2006)
- Representation of small numbers on the left side,
- Faster manual responses, if small numbers on left
- Faster responses, left hand used for small numbers
- Faster to compare 1>9 than 1>3, distance effect
- As numerical distance increases, parietal lobe activation increases (Pinel et al., 2004)
- Implication: Use number line to teach +, -

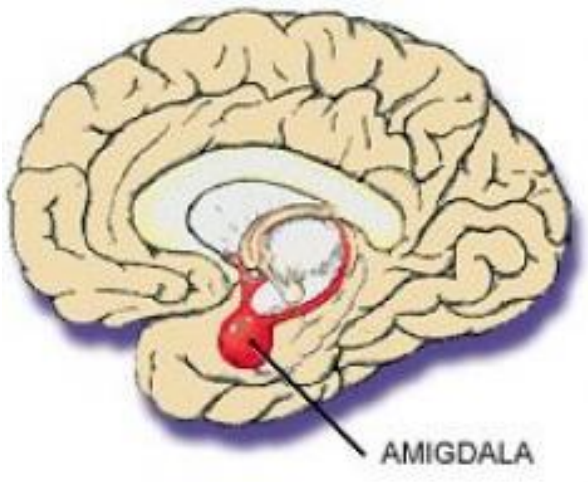
Emotion

- Remembrance of emotional events better than neutral ones
- Associated with amygdala, part of limbic system



Emotion

- Correlation between amygdala activation & memory
- Amydala activation predicts subsequent memory
- No effect of emotion in patients with amigdala damage
- Implication: Add emotion to instruction

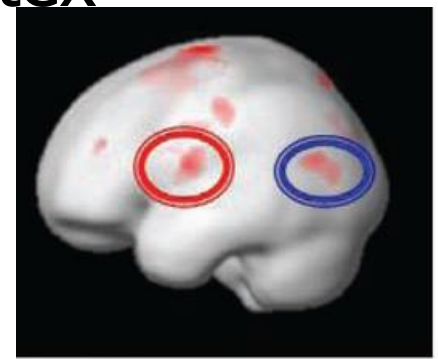


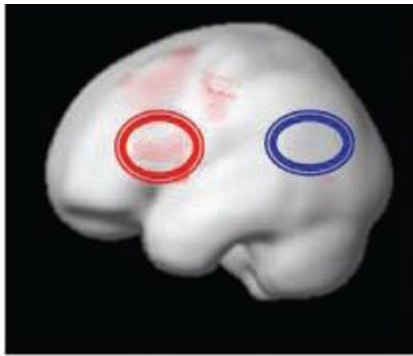
Multimedia

- Presenting visual and verbal info recruits additional brain areas compared to presenting info in one channel (Beauchamp et al., 2004)
  - supporting Dual-coding Theory (Paivio, 1986)
- Encoding visual, compared to verbal info activates additional areas
  - Supporting picture-superiority effect
- No difference in semantic processes (Chee et al., 2000)

Special education

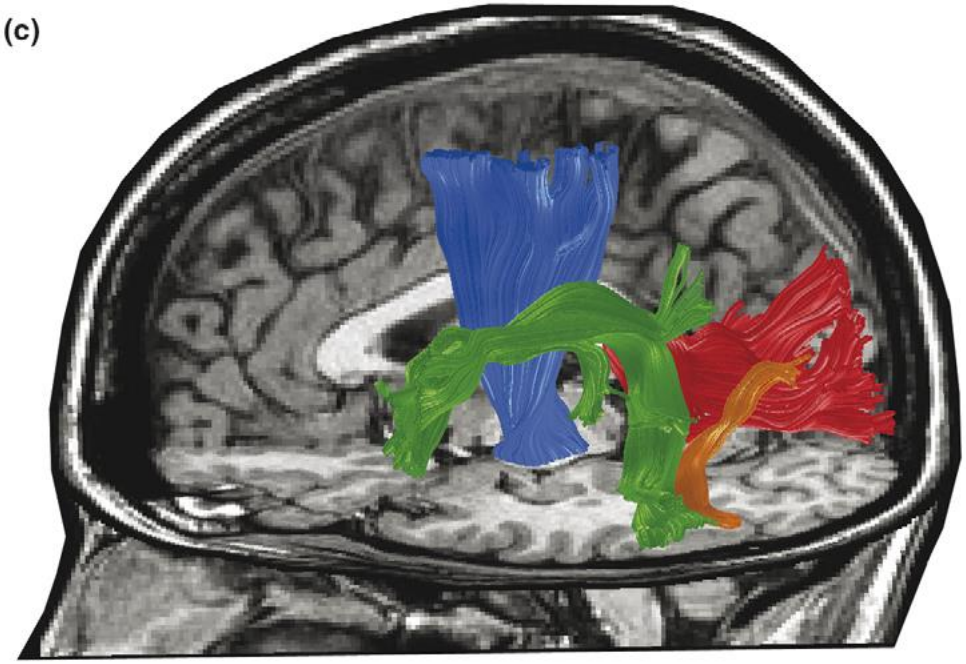
- Dyslexia: difficulty in learning to read, normal intelligence, vision
- Cause: deficit in auditory processing of sounds of language (phonological processing)
- Problem in phonological awareness.
  - Do [leat] and [jete] rhyme?
- Children with dyslexia have small activation in left temporo-parietal cortex





Special education

- DTI (showing neural fiber tracks) studies show that white matter organization is weak in left-posterior for dyslexic



Special education

- Dyslexia can be treated
- Effective treatment associated with higher activation in left temporo-parietal cortex
  - Neuroimaging studies can show effectiveness of treatment

- Dyslexia can be predicted
- Newborns with high risk of dyslexia exhibit different ERP responses to language sound (“ba”, “da”) within hours of birth (Guttorm et al., 2001)
- 81% accuracy of ERP responses for discrimination dyslexic readers at age 8 (Molfese, 2000).

Special education

- Implication: Develop engaging and motivating materials (e.g. games) to improve phonological processing for children

New research opportunities

- Examine cognitive processes that cannot be observed behaviorally
  - Adults faster to perform multiplication than subtraction
  - During multiplication, phonological info retrieval. Sign of look-up verbally coded mental multiplication table
  - During subtraction, visuospatial processes. Sign of imagining and moving along a mental number line (Dehane et al. (2003)

New research opportunities

- Examine cognitive processes that cannot be observed behaviorally
  - Children 3 times slower than adults on number comparison (4 >6?).
  - ERP from parietal lobe are similar for comparison, but children's responding is slower

New research opportunities

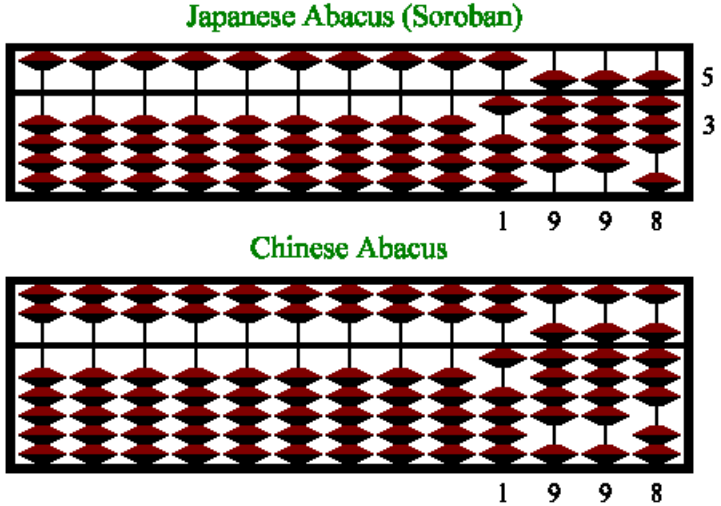
- Examine how different instructional methods or materials affect cognitive processes
  - Delazer et al. (2005) compared two methods for learning arithmetic operations
  - Drill condition activated areas responsible for retrieving verbal info, strategy condition activated areas responsible for retrieving visual imagery

New research opportunities

- Examine developmental changes
  - Rivera et al. (2005) imaged children between the ages of 8 and 19 as they solved simple arithmetic problems
  - Speed increased with age
  - For small children higher frontal activity than adults, increased need for WM and attention
  - For adults, automatization

New research opportunities

- Examine cultural differences
  - Use of motor areas during +, - by Chinese
  - Use of language areas (Broca, Wernieke) by Western
  - Possible reason: Use of abacus



Summary

- Imaging the function of the brain, once considered as a black box
- Neuroscience incredible progress in discovering the neural substrates of mental processes
- Brain research not successfully applied to educational research and practice
- Potential of cognitive neuroscience techniques on conducting novel educational research studies

Questions

fMRI study on cognitive load