Educational Neuroscience

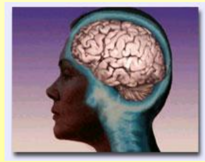
Broadly defined:

The application of cognitive neuroscience methods to learn about phenomena with educational relevance

Our mental life and behaviour relies on the brain.

Neuroscience is the study of the nervous system (including the brain).

The brain can be studied at many different levels:



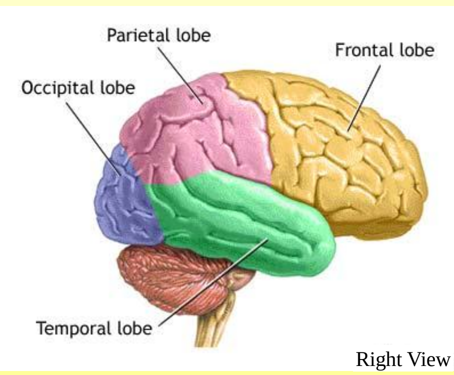
- molecular
- cellular
- anatomical systems
- behavioural level
- mental proceses (functions)

behavioural level + mental proceses → Cognitive psychology

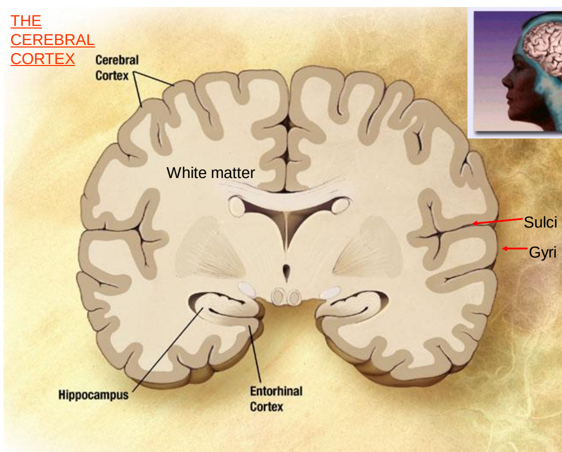
anatomical systems + Cognitive psychology → Cognitive neuroscience

The core of human abilities

Back



Front

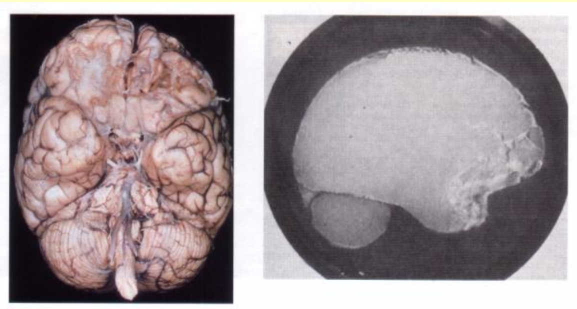


FUNCTIONAL LOCALIZATION

Selective brain damage

Focal lesions

Accidents (e.g. forgotten languages, neglect)



FUNCTIONAL LOCALIZATION

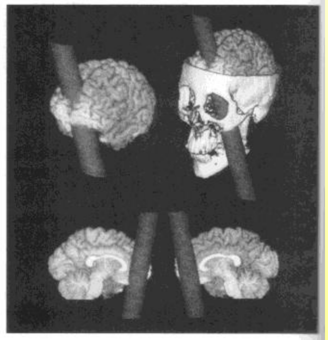
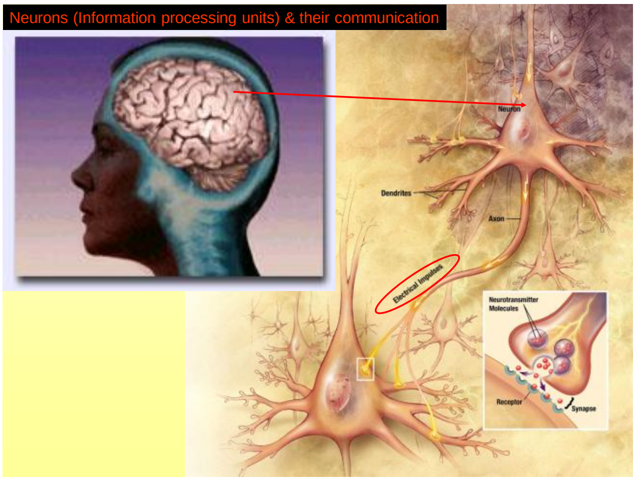


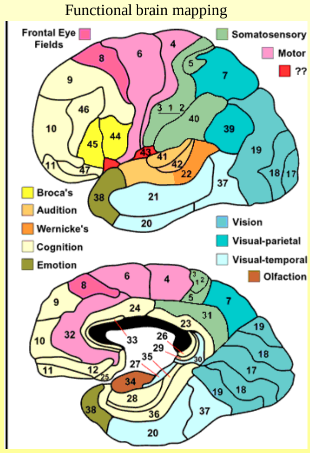
Figure 13.1 Phineas Gage's skull, and computer reconstructions showing how the tamping iron passed through his brain. The iron entered just below the left eye and exited from the top. It destroyed much of the medial region of the prefrontal cortex.

Hanna Damasio et al. Science 1994

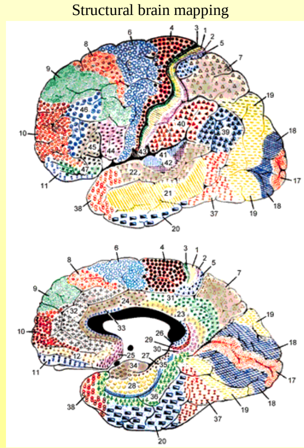
Neurons (Information processing units) & their communication



Functional brain mapping

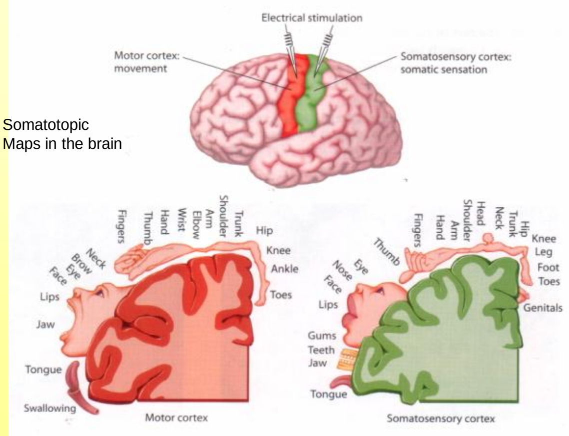


Structural brain mapping

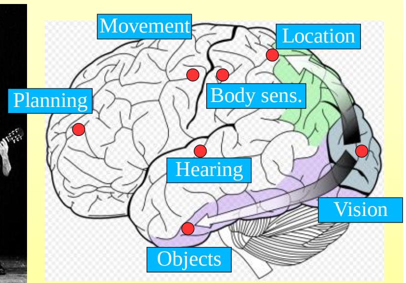


TOPOGRAHIC MAPS

Somatotopic
Maps in the brain

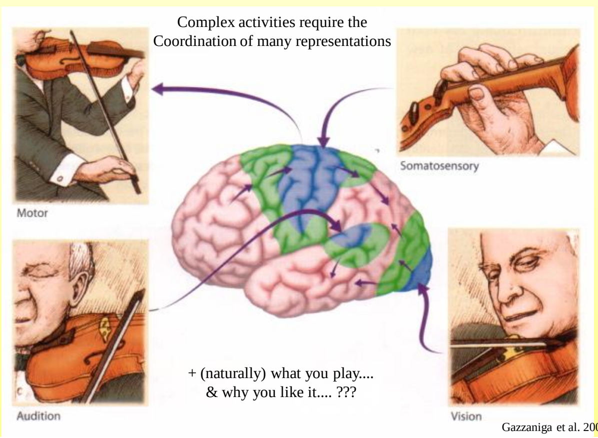


Mental representation: Neural patterns in distributed networks of neurons



The main immediate function of neurons: signalling:
Sending information around in networks.

DISTRIBUTED PROCESSING – complex functions rely on many brain areas



Gazzaniga et al. 2002

Cognitive Neuroscience and Educational Research

Our mental life relies on brain structure and function

Cognitive psychology:
Study of mental **representations and operations** on them:
'The conceptual units of the mind'
How we structure and analyze the world in our mind.

Cognitive neuroscience:
relating hypothesized mental representations to
brain structure and function in relation to mental representations and processes

Education:
systematic shaping of human's mental life (mental representations and processes)

Both Cognitive Neuroscience and Educational research are interested
in the **performance and plasticity of the human brain**

Nevertheless, they study the brain at very different levels.
Is their relationship a bridge too far? (Bruer 1997)

The study of mental representations is useful for educational research as well.
When?

Szűcs & Goswami, 2007, *Mind, Brain and Education*

What is a mental representation?

Wide definition:

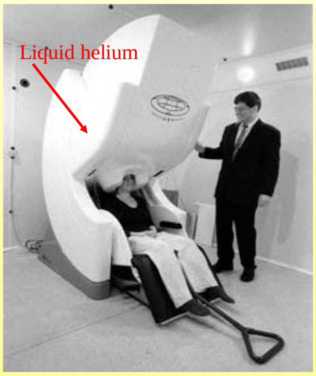
Pattern of neural (brain) activity enabling mental function

Pattern of neural (brain) activity
- coding entities of the world
- neural processes transforming the above codes

Representation:
- code
- and processes operating on these codes

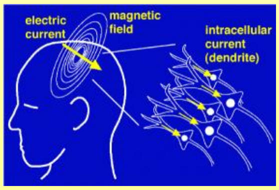
Experimental design
(independent of all the fancy techniques)
is of PRIME importance

Magneto-encephalography (MEG)

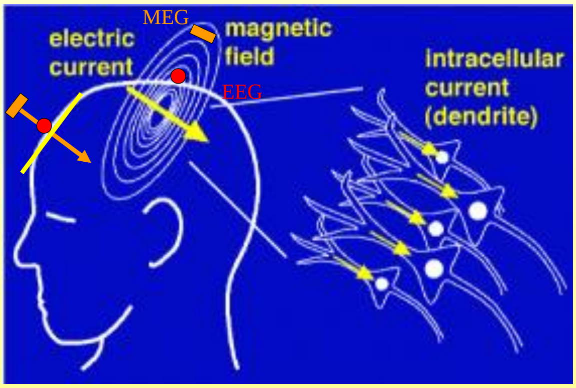


Magnetically shielded room

All metals removed
No body piercing,
Certain tooth fillings
Bullets in body



MEG vs. EEG
Sensitive to differently oriented signals



Combination of methods:

Magneto-
encephalography (MEG)

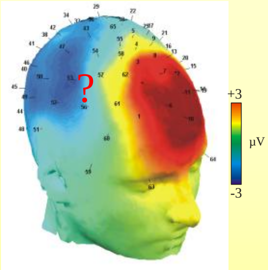
With

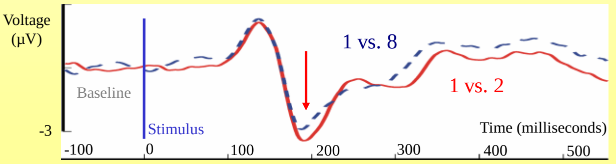
Electro-encephalography

(EEG)

The inverse problem in EEG and MEG

Poor spatial resolution with excellent
Temporal resolution





Average electrical activity at one electrode

Szűcs & Soltész, 2008, *Brain Research*

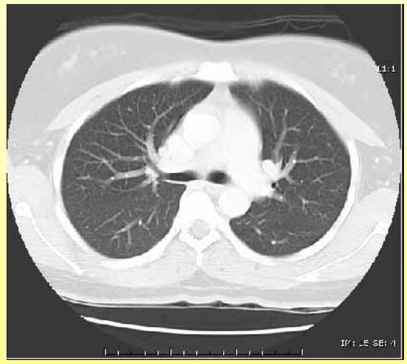
Functional anatomical imaging:

- CT, CAT scan
- MRI: Magnetic resonance imaging: structural and functional
- PET: Positron emission tomography

X-ray

An X-ray picture (radiograph), taken by Wilhelm Röntgen in 1896,
of his wife, Anna Bertha Ludwig's hand

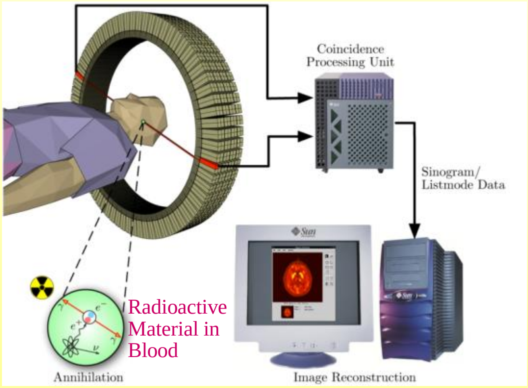
Chest X-ray



CAT-scan
Computed Axial Tomography

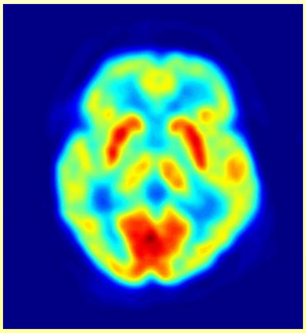
CAT-Scan

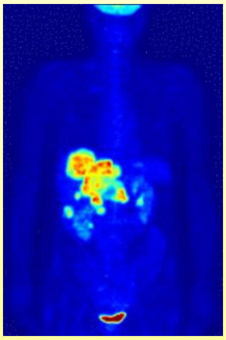
PET Scanner



Brain: 2% of body mass; 20% of oxygen; max 10 mins tolerance to O loss

PET





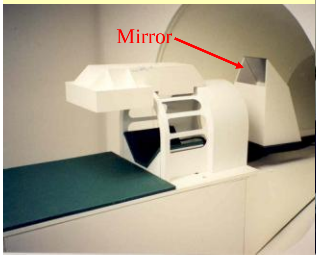
Whole body

Brain; rCBF:
Regional Cerebral Blood Flow
Assumption: more blood, more brain activity
Blood: glycose (sugar) and oxygen

MRI Scanner

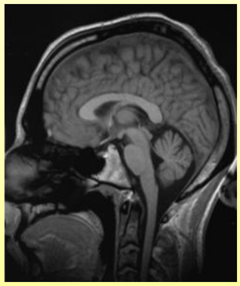
Wikipedia.org

Functional Magnetic Resonance Imaging (fMRI) & PET



MRI: Magnetic resonance imaging

Structural MRI



3D anatomical image of the brain

Measurement by usign strong magnetic field

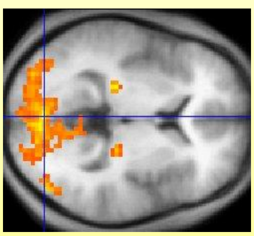
MRI: 1.5 to 4.0 or 7.0 Tesla
Earth: 5×10^{-5} (0.00005) Tesla

Measurement depends on different magnetic properties of tissues

(e.g. Grey, White matter, blood vessles)

MRI: Magnetic resonance imaging

fMRI: functional MRI



Measuring the oxygen content of blood by magnetic fields [MF]

Assumption: More oxygen is used where the brain is more active

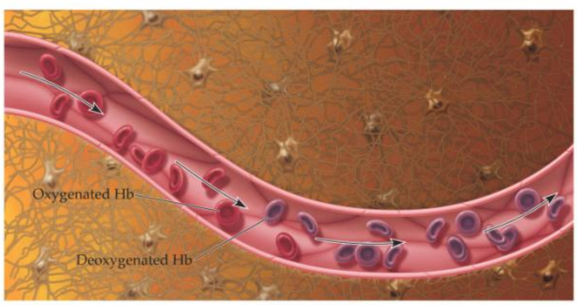
(Oxygen is attached to Hemoglobine [HB] in blood)

Oxygenated HB repulses from MF (diamagnetic)
De-oxygenated HB is attracted to MF (paramagnetic)

Magnetic suspectibility (intensity of magnetisation) of de-oxygenated blood is 20% greater than that of fully oxygenated blood

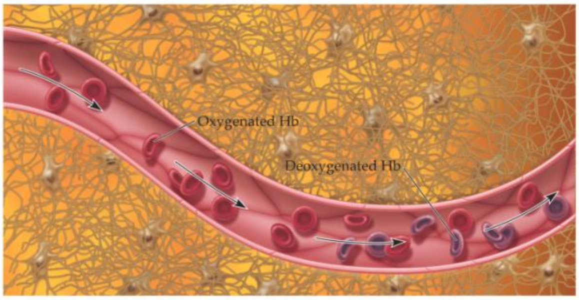
Measuring the proportion of de-oxygenated and oxygenated blood

(A)



FUNCTIONAL MAGNETIC RESONANCE IMAGING, Figure 7.14 (Part 1) © 2004 Sinauer Associates, Inc.

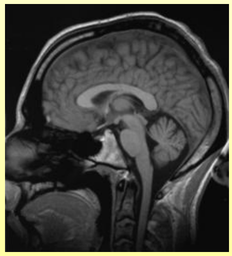
(B)



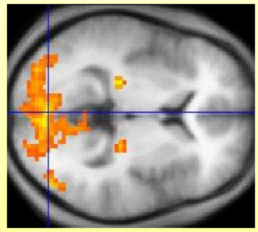
FUNCTIONAL MAGNETIC RESONANCE IMAGING, Figure 7.14 (Part 2) © 2004 Sinauer Associates, Inc.

MRI: Magnetic resonance imaging

Structural MRI



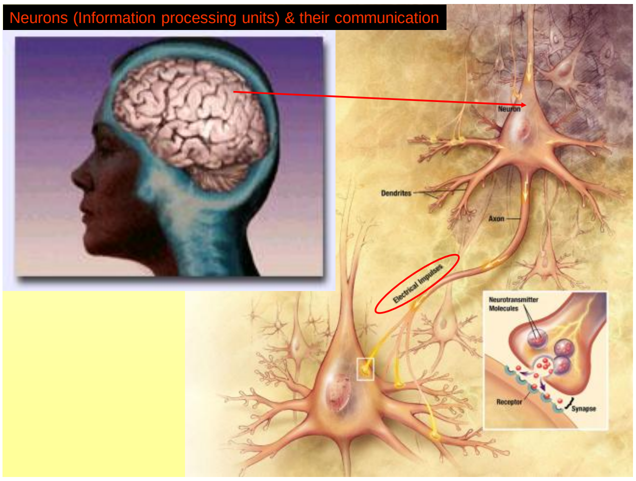
fMRI: functional MRI



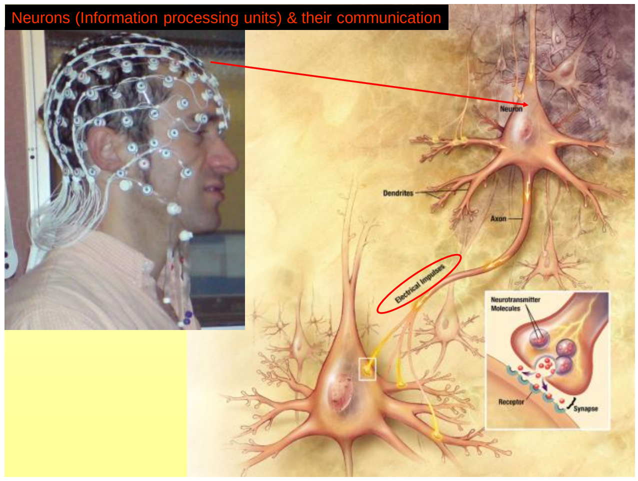
fMRI is good to study anatomical hypotheses:
Where is something happening in the brain?

However, its temporal resolution is poor (seconds).

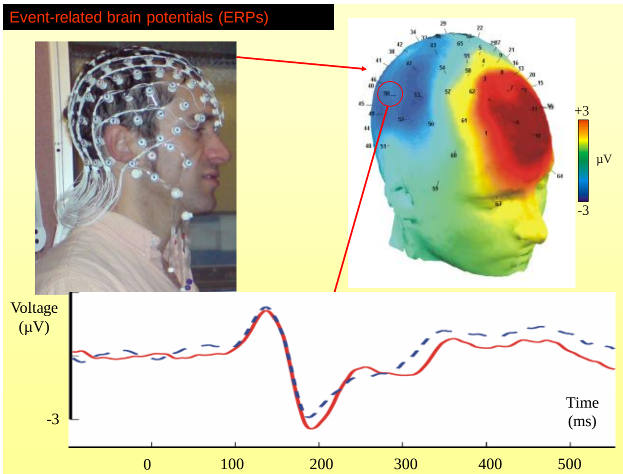
Neurons (Information processing units) & their communication



Neurons (Information processing units) & their communication

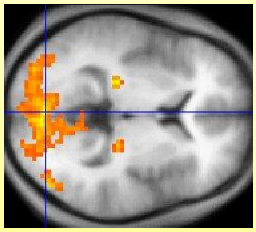


Event-related brain potentials (ERPs)



EEG signal differs hugely from fMRI signal which measures blood flow (not direct neural activity)

fMRI: functional MRI



Measuring the oxygen content of blood by **magnetic fields** [MF]

Measuring the **proportion** of de-oxygenated and oxygenated haemoglobin in blood (**BOLD signal**) (Oxygen is attached to Hemoglobine [HB] in blood)

Assumption: **More oxygen** is used where the brain is more active

Oxygenated HB repulses from MF (diamagnetic)
De-oxygenated HB is attracted to MF (paramagnetic)

Magnetic suspectibility (intensity of magnetisation) of de-oxygenated blood is 20% greater than that of fully oxygenated blood

EEGs vs. fMRI

	Temporal Resolution WHEN	Spatial Resolution WHERE
ERP	Good 1 millisecond or better	Bad From several centimeters to unknown
fMRI	Bad From half a second to Several seconds	Good Can be half a centimetre

The laboratory setting:
very different from a classroom setting! (ecological validity)

General methodological problems in the laboratory environment

- Laboratory settings (**strange** environment)

- Environmental noise (affecting the equipment or the subject)
  -> **Silent, deprived environment**

- Subject noise (not environmentally induced)
  - Performance fluctuations, strategy change (complex tasks)
  - Movement (**constrained settings**), **heartbeats**, **blinks**

- Paradigm design
  (**unexciting and repetitive** tasks)

- **Large quantity of data** must be analyzed.
  - 500 samples per second x 64 electrodes x 60 minutes
  = 115,200,000 samples

- Children: All difficulties multiplied by 10

When is neuroscience **useful**?

When it can tell you something which cannot be Determined from behavioural data **alone**.

When is neuroscience **useful** for education research?

When it can tell you something which **cannot** be determined from behavioural data **alone**.

- **Why** is good to have neuroscience data?
- **What kind** of neuroscience data should I have?
  This depends on the **strengths/weaknesses** of methods.
  If you ask about **anatomy**, use fMRI
  If you ask about **timing**, use EEG
- Is the **laboratory environment** an appropriate model?
  (it is not for example, for studying classroom interactions)

Below comes an **example** which demonstrates a situation When neuroscience data can deliver information that Cannot be determined from behavioural data....

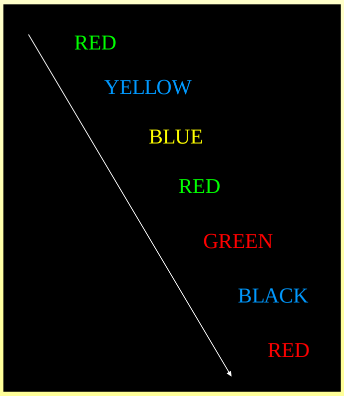
The color-word Stroop task in Developmental research

What is the **INK** color?

A good model of
Decision making
With distraction

Development:
Response inhibition:
An important skill
Emerging through
Development

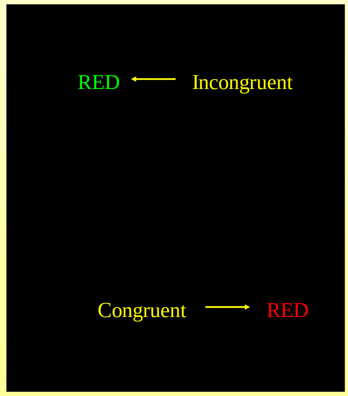
Direct impact on e.g.
Control of behaviour
In School.



Stroop 1935

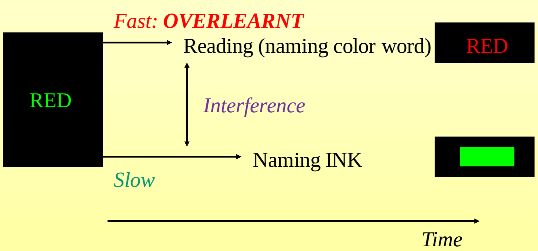
Classical color-word Stroop task:

What is the INK color?



Stroop 1935

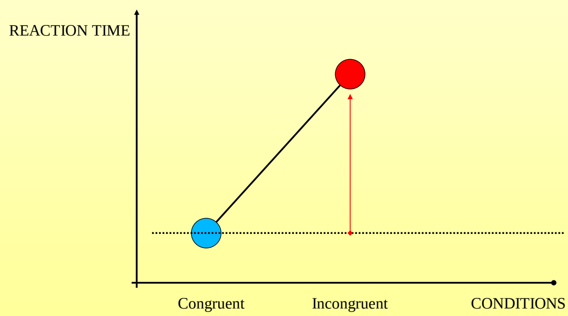
Basic model of the Stroop effect: Parallel processing



Stroop 1935

Two main theories of typical behavioral results in Stroop task

Slowing down is due to...
1) Resolving conflict between perceptual/semantic features
2) Main source of conflict is incorrect response activation



Two **theories** of behavioral results in Stroop task

Slowing down is due to...
1) Resolving conflict between perceptual/semantic features
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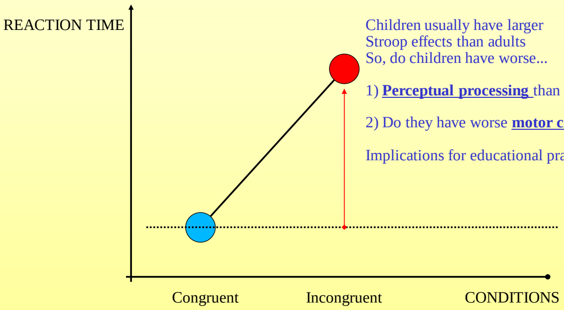


Children usually have larger Stroop effects than adults
So, do children have worse...

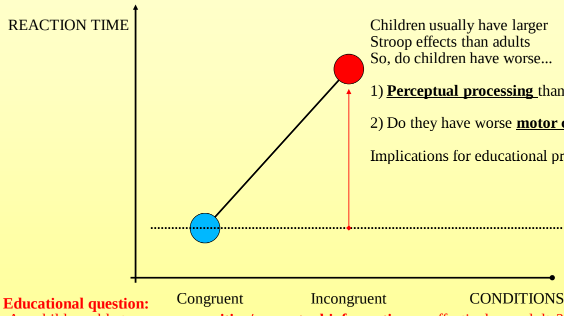
1) **Perceptual processing** than adults?

2) Do they have worse **motor control**?

Implications for educational practice!

Two **theories** of behavioral results in Stroop task

Slowing down is due to...
1) Resolving conflict between perceptual/semantic features
2) Main source of conflict is incorrect response activation



Children usually have larger Stroop effects than adults
So, do children have worse...

1) **Perceptual processing** than adults?

2) Do they have worse **motor control**?

Implications for educational practice!

Educational question:
-Are children able to process **cognitive/perceptual information** as effectively as adults?
- If they can; **can they interface/use this information** with the **motor system** effectively

NOT POSSIBLE TO DECIDE BY BEHAVIOURAL METHODS ALONE

5-8 year-old children in the laboratory

Szűcs D et al. 2009. Journal of Cognitive Neuroscience.

The **CHILD FRIENDLY** experimental paradigm
Which animal is larger in real life? (Moyer, 1973)
Press the response button on that side
(Animals were known to children; and rated as big or small by children)

Conditions

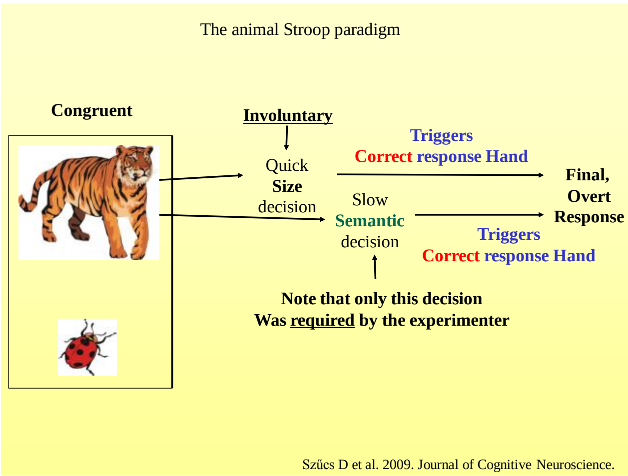
Congruent 2 8

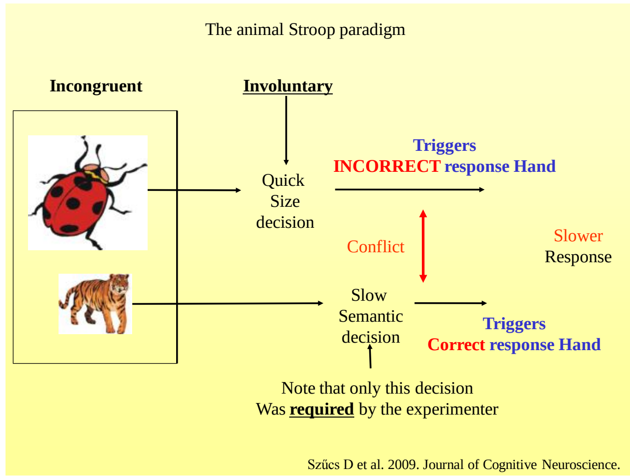
Press RIGHT

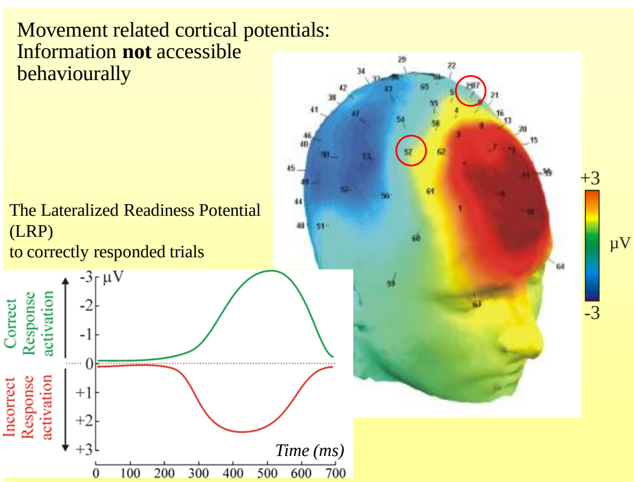
InCongruent (conflicting) 2 8

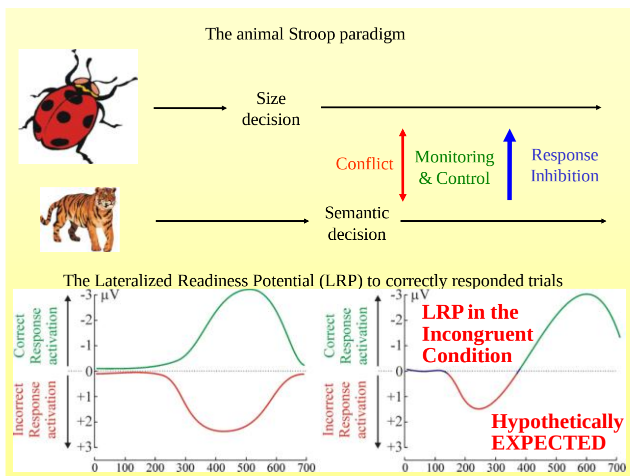
Press RIGHT

Szűcs D et al. 2009. Journal of Cognitive Neuroscience.

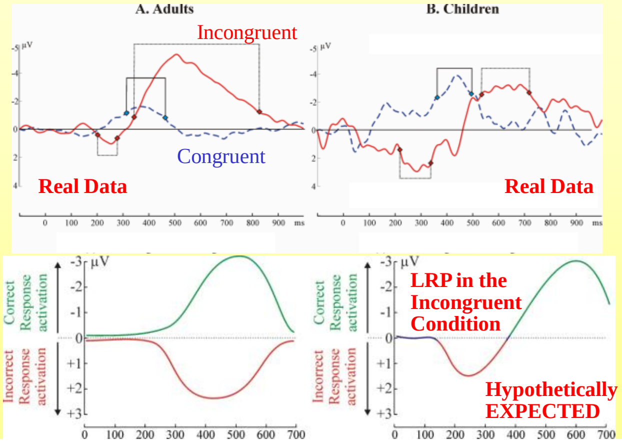

The animal Stroop paradigm
Congruent
Involuntary
Quick
Size
decision
Triggers
Correct response Hand
Final,
Overt
Response
Slow
Semantic
decision
Triggers
Correct response Hand
Note that only this decision
Was required by the experimenter
Szűcs D et al. 2009. Journal of Cognitive Neuroscience.


The animal Stroop paradigm
Incongruent
Involuntary
Quick
Size
decision
Triggers
INCORRECT response Hand
Conflict
Slower
Response
Slow
Semantic
decision
Triggers
Correct response Hand
Note that only this decision
Was required by the experimenter
Szűcs D et al. 2009. Journal of Cognitive Neuroscience.

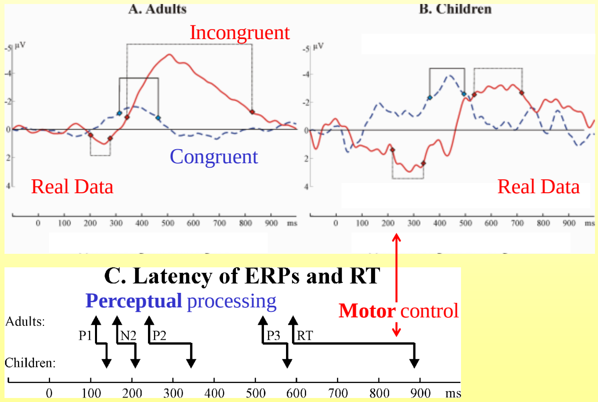

Movement related cortical potentials:
Information not accessible
behaviourally
The Lateralized Readiness Potential
(LRP)
to correctly responded trials
+3
μV
-3
Correct Response activation
Incorrect Response activation
-3 μV
-2
-1
0
+1
+2
+3
Time (ms)
0 100 200 300 400 500 600 700


The animal Stroop paradigm
Size
decision
Conflict
Monitoring
& Control
Response
Inhibition
Semantic
decision
The Lateralized Readiness Potential (LRP) to correctly responded trials
Correct Response activation
Incorrect Response activation
-3 μV
-2
-1
0
+1
+2
+3
0 100 200 300 400 500 600 700
LRP in the
Incongruent
Condition
Hypothetically
EXPECTED

Lateralized Readiness Potential (LRP) to correctly responded trials



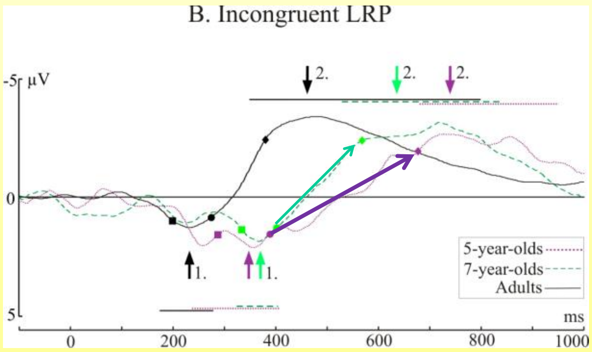
Lateralized Readiness Potential (LRP) to correctly responded trials



Szűcs et al. 2009. *J Cognitive Neuroscience*

Lateralized Readiness Potential (LRP) to correctly responded trials

Conclusion: correction of incorrect motor tendency is much slower in younger than older children



Bryce, Szűcs et al. 2011. *NeuroImage*

Educational questions

-Are children able to process **cognitive/perceptual information** as effectively as adults?
- At least in the Stroop task context **they can**

- If they can; can they interface this information with the **motor system** effectively?
- **No, their efficiency is much worse than that of adults**.

The above data could not be accessed by behavioral methods because **you have to observe incorrect response activation explicitly.**

Hence, here EEG provides a unique possibility to collect **data otherwise inaccessible** for research which can inform practice.

Classroom implications:

Children may process some information perceptually but may be unable to act upon it effectively.

When is neuroscience **NOT useful**?

When it can tell you **nothing** which is already not evident from the behavioural data.

E.g.
- The brain is the basis of our mental life >
- The brain does everything >
- From the point of view of education **it is not too informative to show that a particular part of the brain does a particular function**... (e.g. This may be important for a doctor, though...)
- Provided you do not say anything else as already known from behavioural data...

(However, it is 'sexy'! .....)

Two main questions:

1. Why is this brain-based explanation **interesting** for me?
   (is it useful for me to know this?)
   A. It is interesting because I **like to know more** about the brain
   B. It is interesting because it is **useful** for me to know more about education
   A does not equal B

2. Do I have the **methodological** knowledge to judge the value of a report?

Beware of the popular science press!
BBC about the brain: 15:00 GMT, Tuesday, 14 October 2008 16:00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Entertainment

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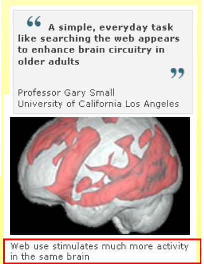
Internet use 'good for the brain'

For middle-aged and older people at least, using the internet helps boost brain power, research suggests.

A University of California Los Angeles team found searching the web stimulated centres in the brain that controlled decision-making and complex reasoning.

The researchers say this might

Areas activated by reading a book in the brain of an experienced web user


" A simple, everyday task like searching the web appears to enhance brain circuitry in older adults "

Professor Gary Small
University of California Los Angeles

Web use stimulates much more activity in the same brain