The Open University

The neuroscience of teaching physics

Stephen Swithenby

Physics Higher Education Conference 2008

Agenda

Neuroscience and education?

Background – functional imaging

Illustration - understanding autism

Learning algebra – the problem

Pilot data

Next steps

Neuroscience and Education

Is neuroscience relevant?

'……only by understanding behaviour can we understand the brain—there's very little in terms of explanatory value coming back the other way. We simply don't know enough yet. Brain science may never be that relevant …' John Bruer

Myths and exaggerations

Right/left brain

Gardner's multiple intelligences - linguistic, logical-mathematical, musical, bodily, spatial, interpersonal, intrapersonal

Focus on early learning. 'I*t is clear that by the time most children start preschool, the architecture of the brain has essentially been constructed.'* Hilary Clinton

Neuroscience in education - a new market

Scientific Learning ~£50M per year Fast ForWord (Paula Tallal (Rutgers) and Michael Merzenich (UCSF emeritus)

Academic ideas

- Auditory/written interdependence
- Reading difficulties linked to auditory deficit in distinguishing phonemes
- Intensive training

… we applaud the efforts to distribute the public benefits of this work. …. No clear path to follow in ensuring that their new products are fully tested. Nature Neuroscience

ELL:

The language of success.

"We were failing the ESL and Special Ed kids and I wanted to fix that."

READ MORE

MORE STORIES OF SUCCESS:

AT-RISK: NO DISTRICT LEFT BEHIND.

GENERAL EDUCATION: EXCEEDING EXPECTATIONS.

SPECIAL EDUCATION: THE MOMENT HIS LIFE CHANGED.

Scientific Learning strengthens brain processing efficiency for learning and reading success.

Fit Brains Learn Better.

Fast ForWord® Family of Products

VIEW PRODUCTS REQUEST INFO

Proven software solutions that boost students' processing efficency and reading ability with enduring gains.

EVENTS

See Us on Lifetime Television Network

Scientific Learning was recently featured on **"The Balancing Act"**. The segment discusses the concept of brain plasticity and demonstrates how our products can strengthen brain processing and literacy skills. **Watch now!**

MORE EVENTS

DID YOU SEE US ON?

THE BALANCING act

THE DAILY TELEVISION SHOW

EVERY WEEKDAY AT 7AM, 6AM CST Lifetime

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Carnegie Learning

Spin off from Carnegie Mellon - 500k students

Tutoring software (incl. Math solutions)

Cognitive science informed

Based on Adaptive Control of Thought Rational

ACT-R model of cognition (JR Anderson)

declarative & procedural knowledge

practice designed to move from

declarative to procedural

Neuroscience and Education

Is neuroscience relevant?

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Neuroscience and Education

Michael Atherton

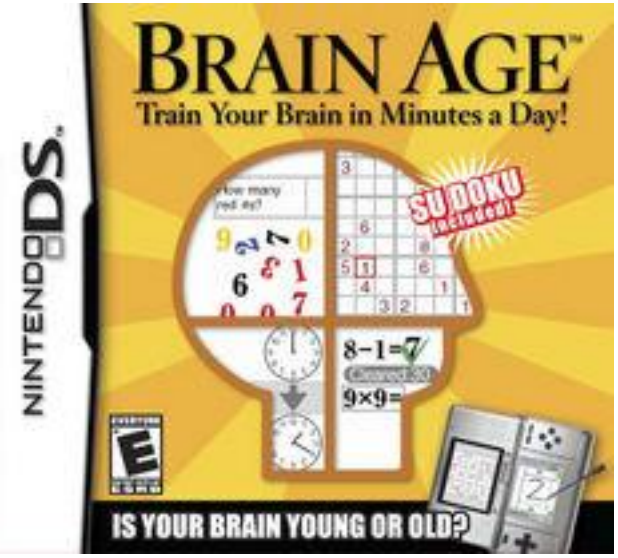
- Inform interdisciplinary perspectives and allow testing of hypotheses, e.g. dual approach to reading
- Change in theories of cognition and education, e.g. constructivism
- Identification and testing of specific interventions – building an empirical database, i.e. the educational trial or EBT
- Providing models for teachers, educational researchers and policy makers, e.g. front loaded or lifelong learning

Testing of neuroscientifically grounded hypotheses about learning & about problems faced by teachers

For example

The maths problem

Symbolic maths as an acquired language
The transition from being able to being expert

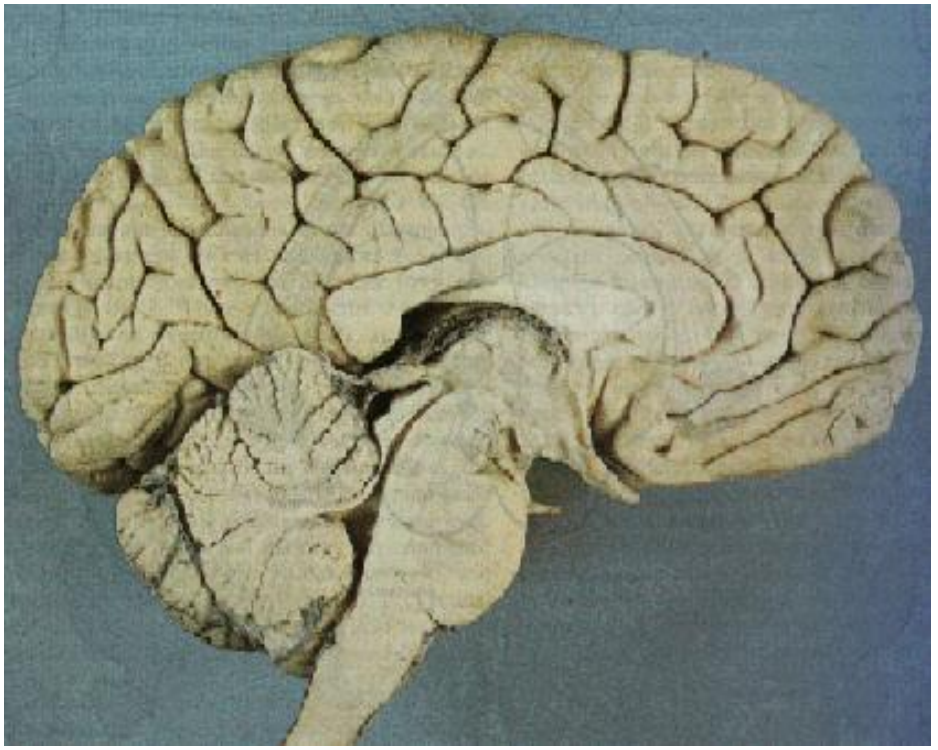


The role of repetition in deeper learning
The balance of novelty, rote and engagement

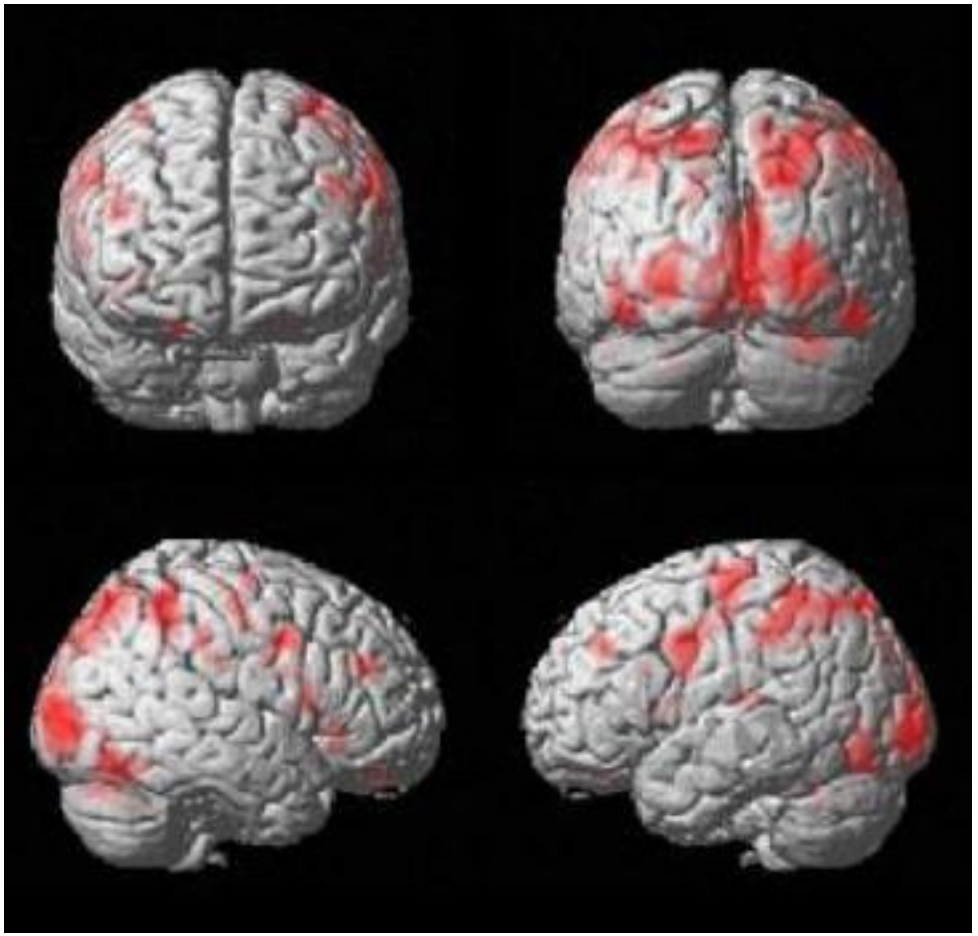
Imaging the human brain

- 100,000,000,000 cells
- Half involved in information processing
- Up to 50,000 connections per cell

and it changes all the time!



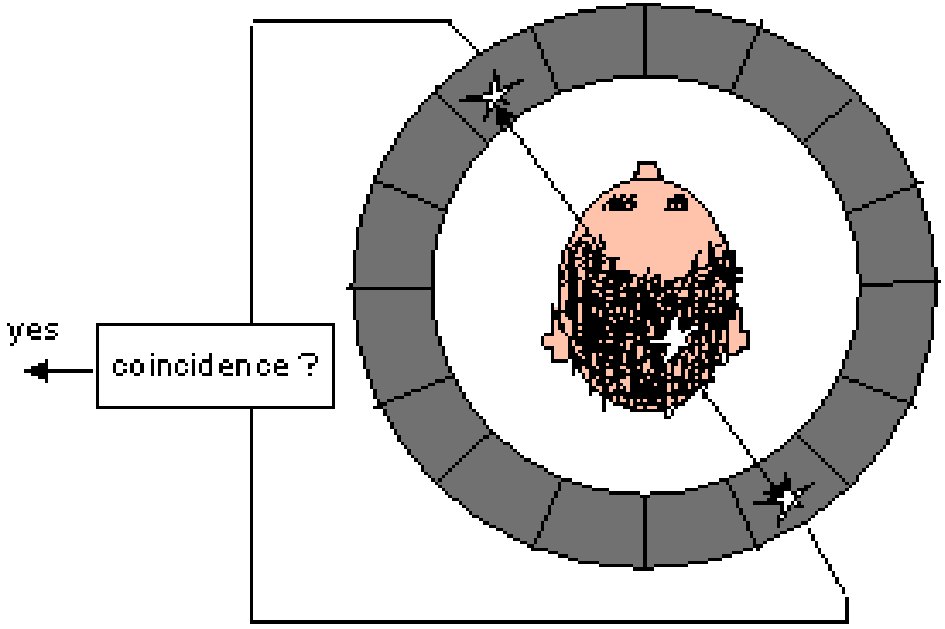
Functional imaging - fMRI



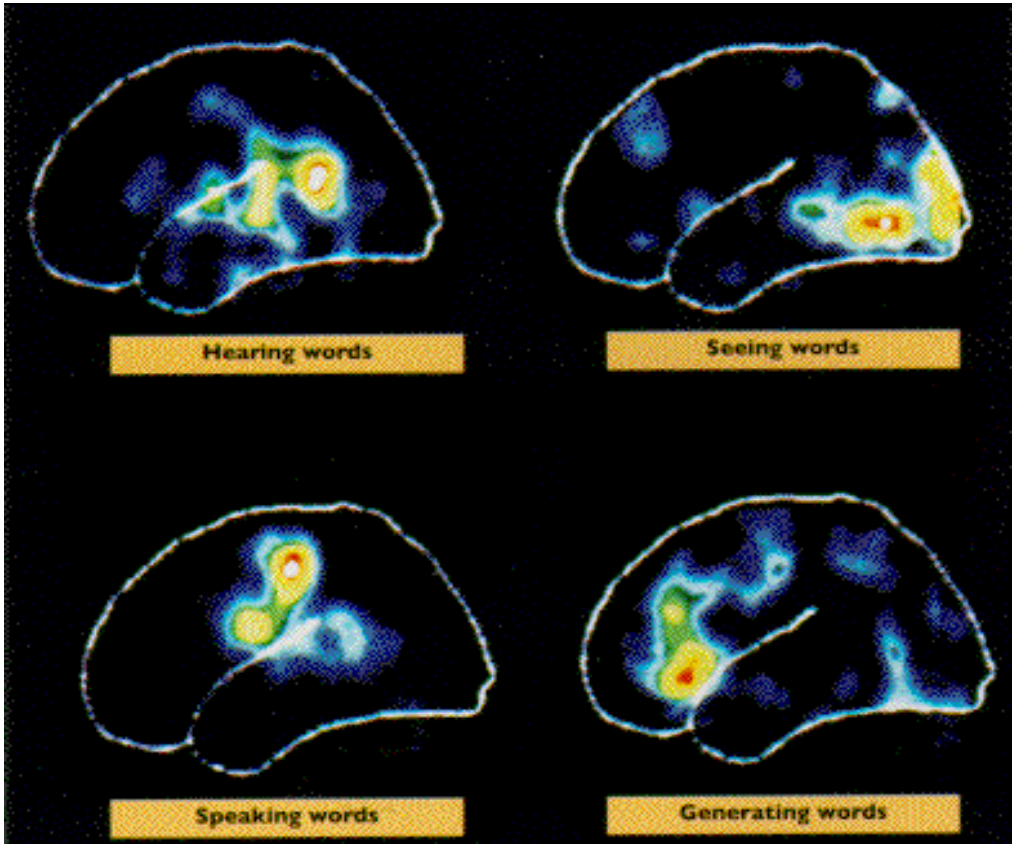
The MRI signal is slightly affected by the oxygen in the blood. By repeating an MRI measurement we can compare the oxygen levels in the brain at the two times.

Resting vs braille reading

Positron Emission Tomography



In PET, emitted positrons meet electrons, are annihilated and produce two coincident gammas.



By repeating a measurement, we can compare the distribution of the radiochemical at the two times.

Brain imaging techniques

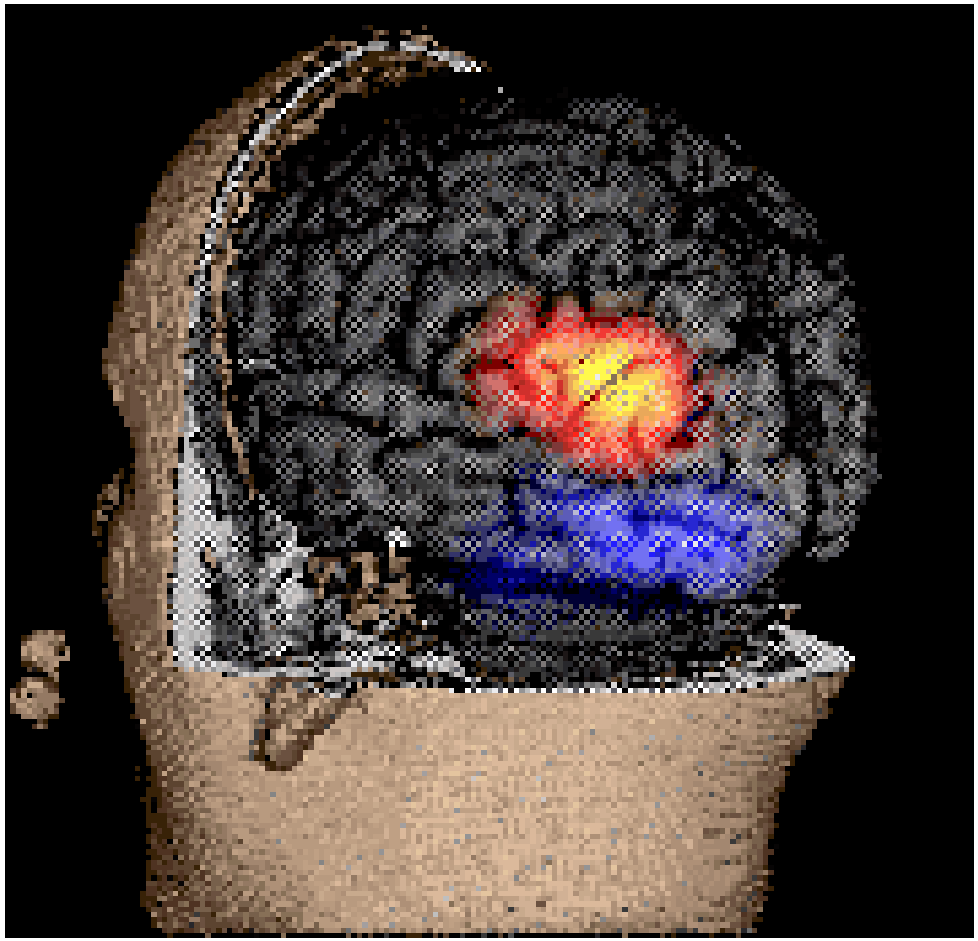
Both fMRI and PET measure blood flow.

Time resolution is minutes for PET and
~1 second for fMRI

Can we image activity at the rate at which brains work

Magnetoencephalography

- Currents in the brain produce very weak magnetic fields
- Superconducting sensors SQUIDs
- Map back from fields to the currents
- Hence maps of currents, i.e. activity



An MEG ‘Scanner’

Several hundred detectors at 4.2K

Helmet shaped detection area

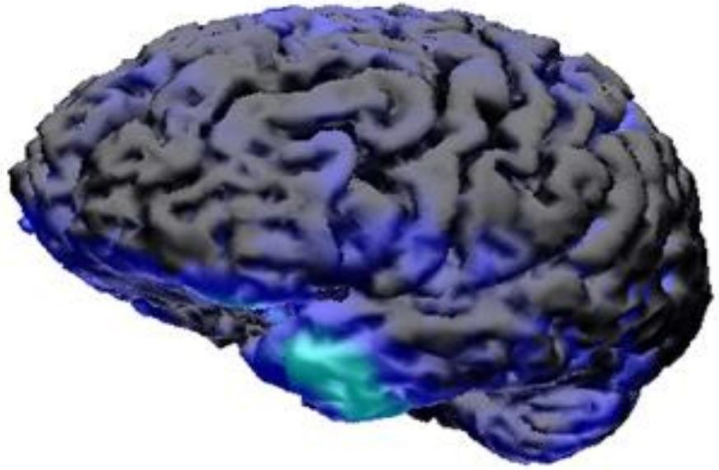
Non invasive

Continuous recording

Magnetic noise reduction

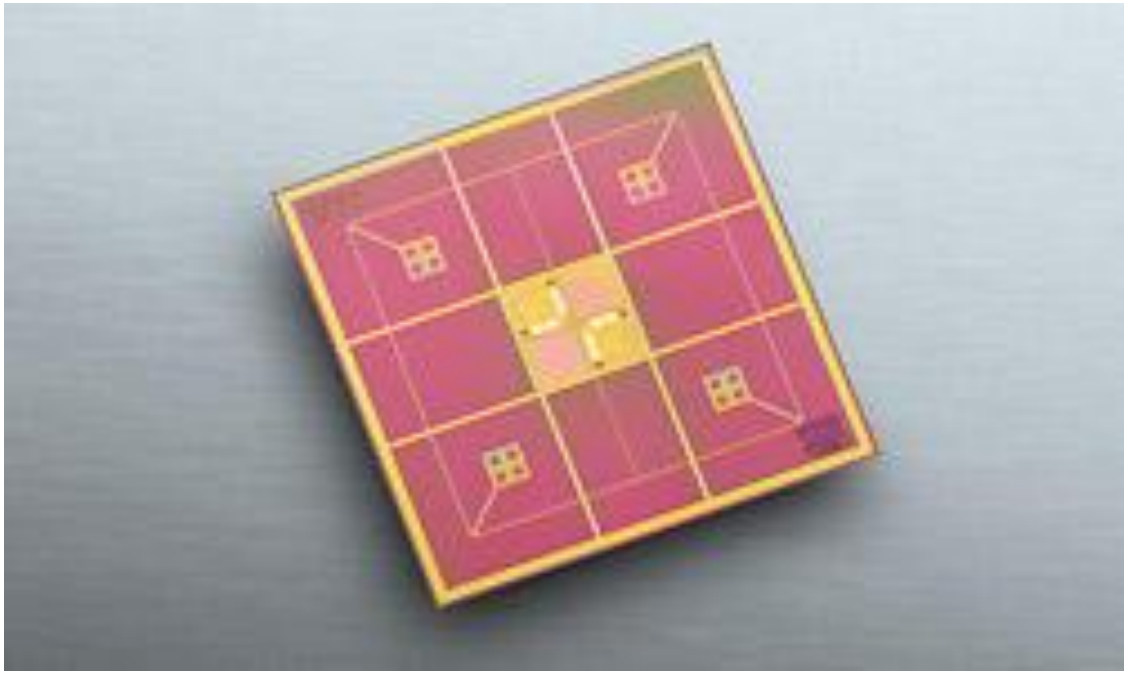
Modest spatial resolution

High time resolution



Detectors

Superconducting coils linked to Superconducting Quantum Interference Devices



Neuromag Elekta

MEG Signals

Several hundred detectors at 4.2K

Helmet shaped detection area

Non invasive

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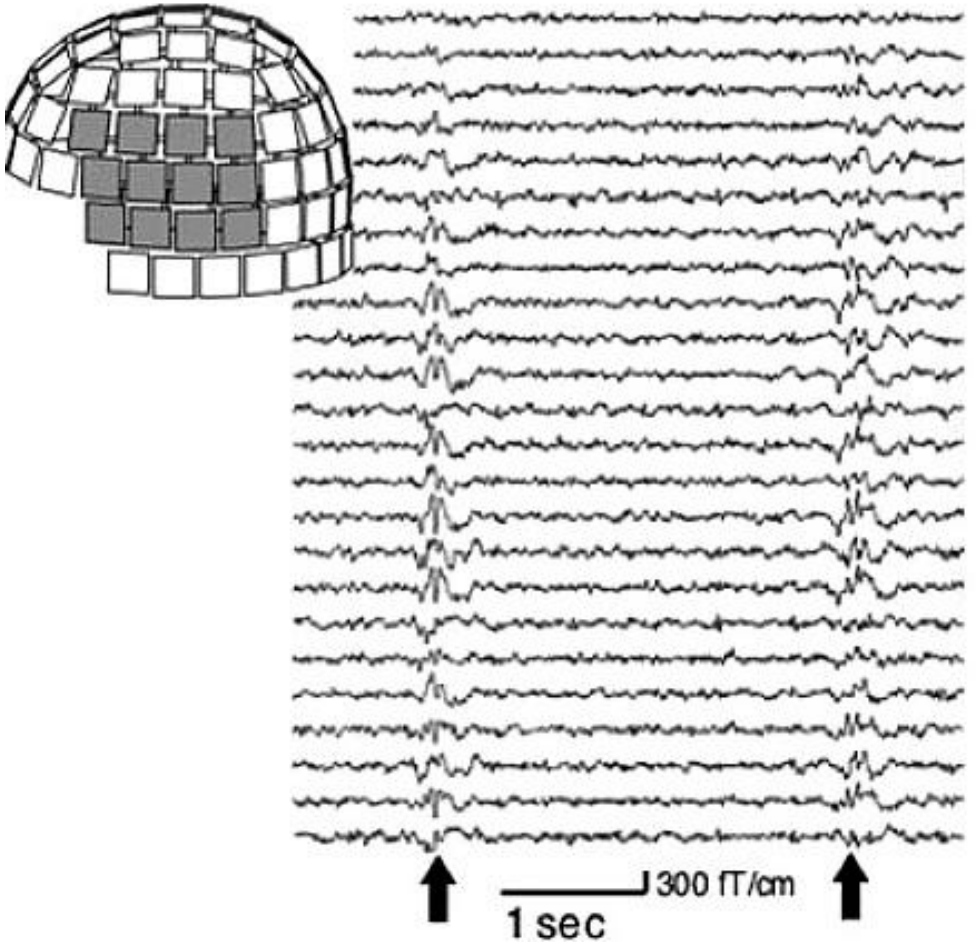
Magnetic noise reduction

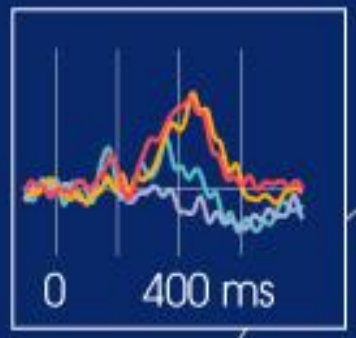
Modest spatial resolution

High time resolution



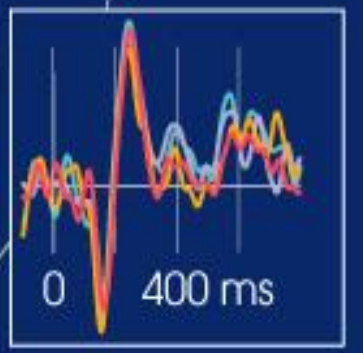
Kamimura et al
EPILEPSIA 47 (6) JUN 2006

Reading Comprehension: Responses to Final Words



1 fluent reader

expected
rare
anomalous
phonological



-100...800 ms

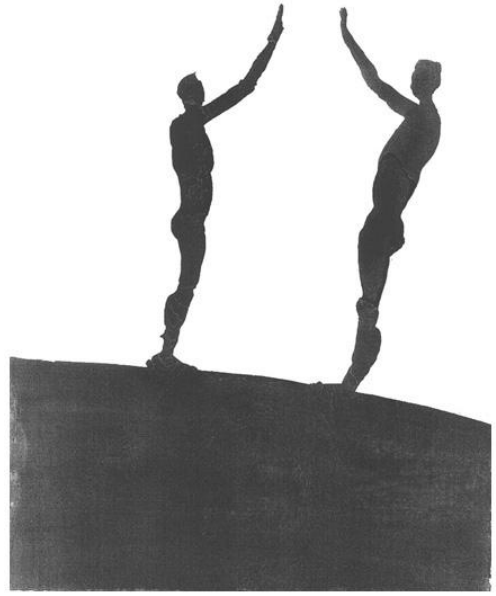
Helenius et al.
Brain, 1998

Autism – MEG study

Aim is find the neurophysiological basis of autism

Choose tasks where there are clear behavioural differences, e.g. face processing. Escalate demands on high functioning subjects (adults & children) until the behavioural deficit is reflected in the MEG response

Identify the neurophysiological systems that are different.



Face processing studies

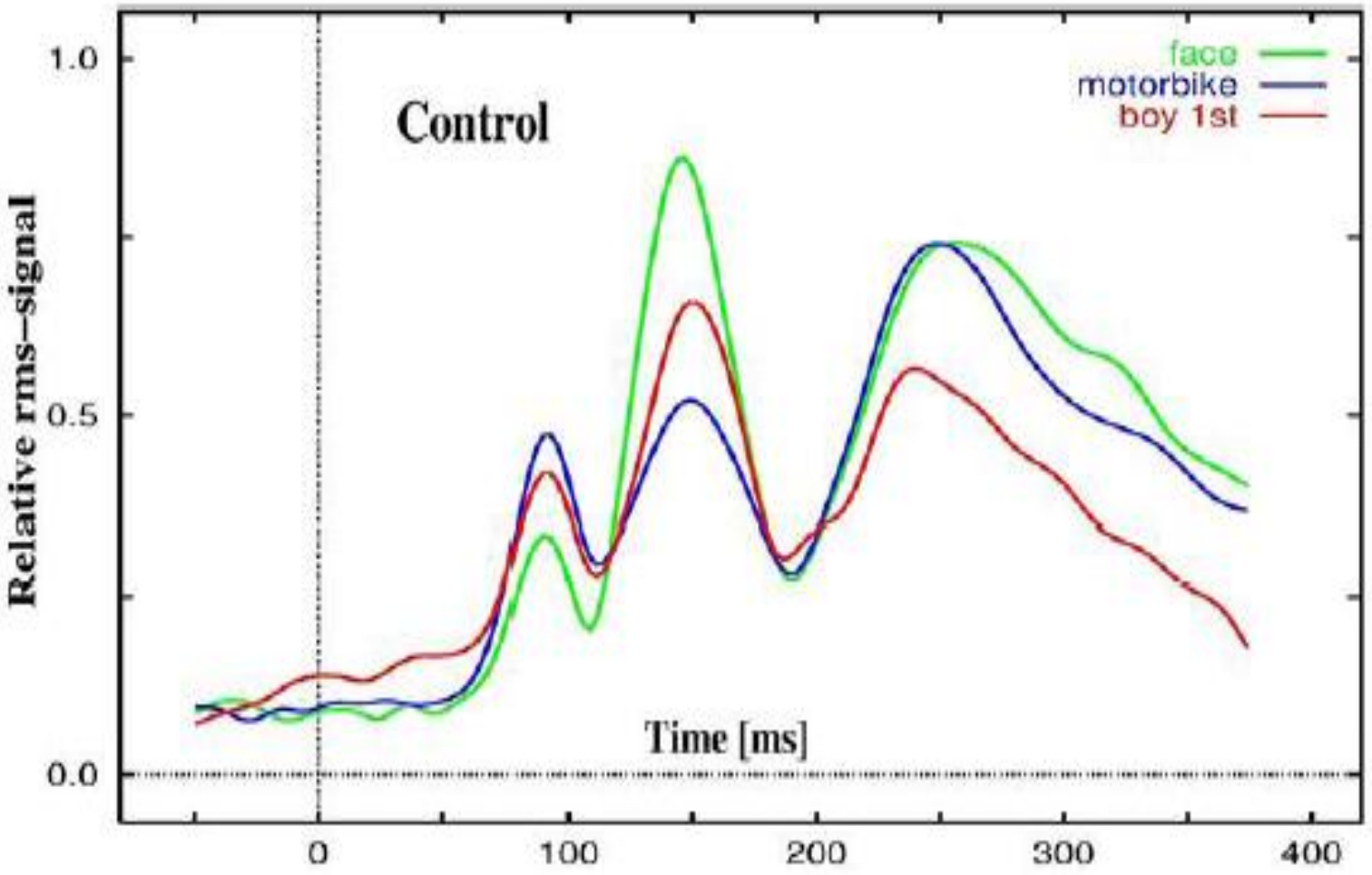
Task 1 Identify faces

Task 2 Identifying identical faces

Task 3 Identify emotional state

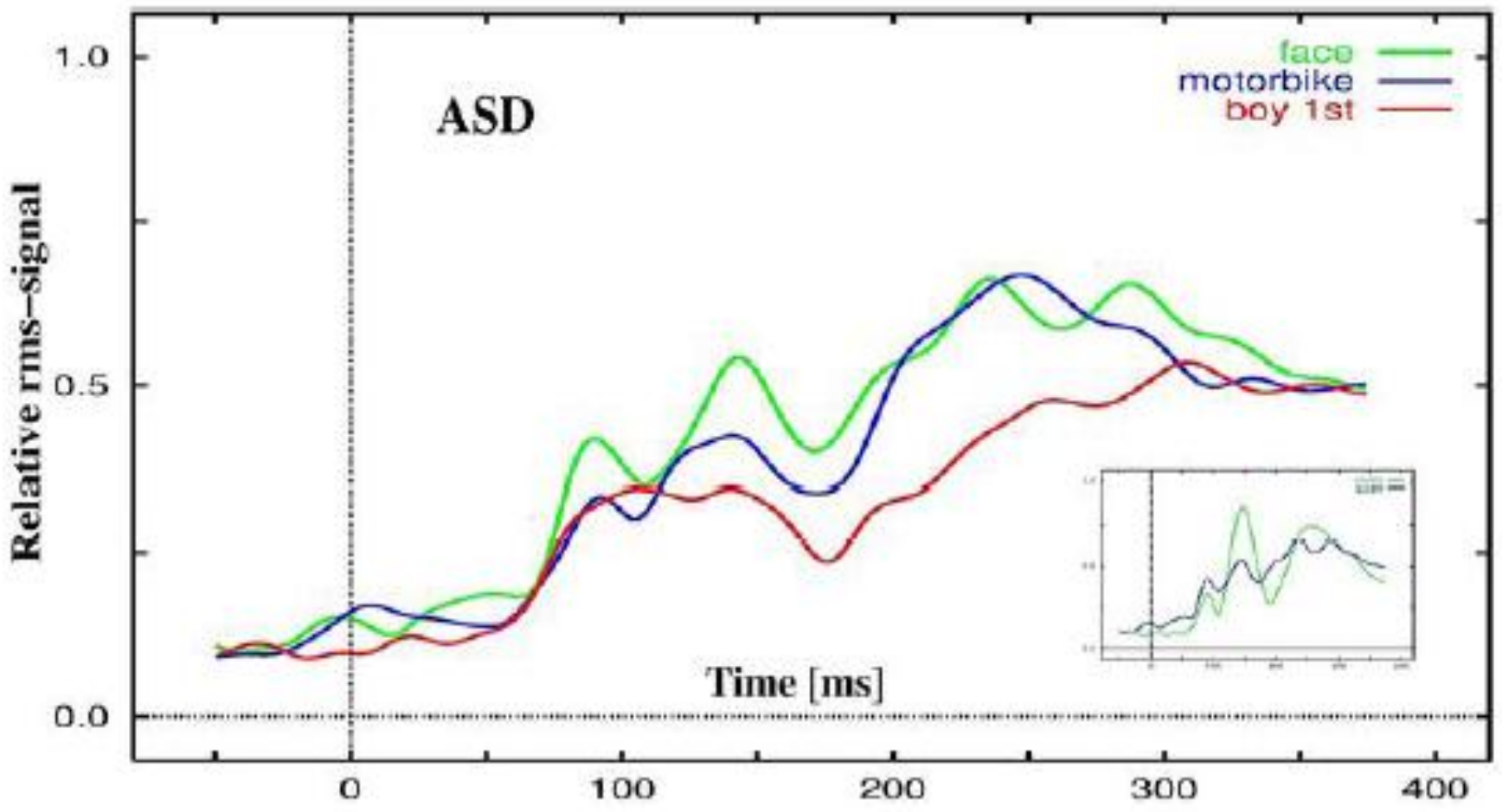
Task 4 Identify same individual with different emotions

Face responses - control adults



Note three peaks

Face responses - autistic adults



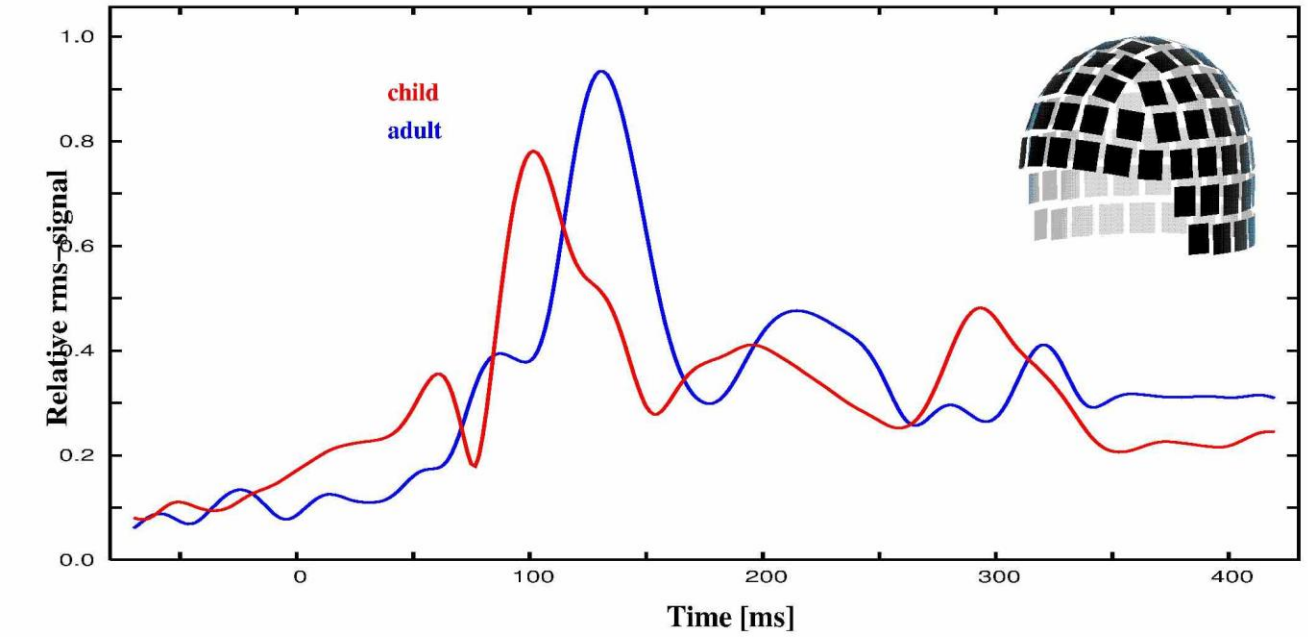
Still three peaks but less defined against background

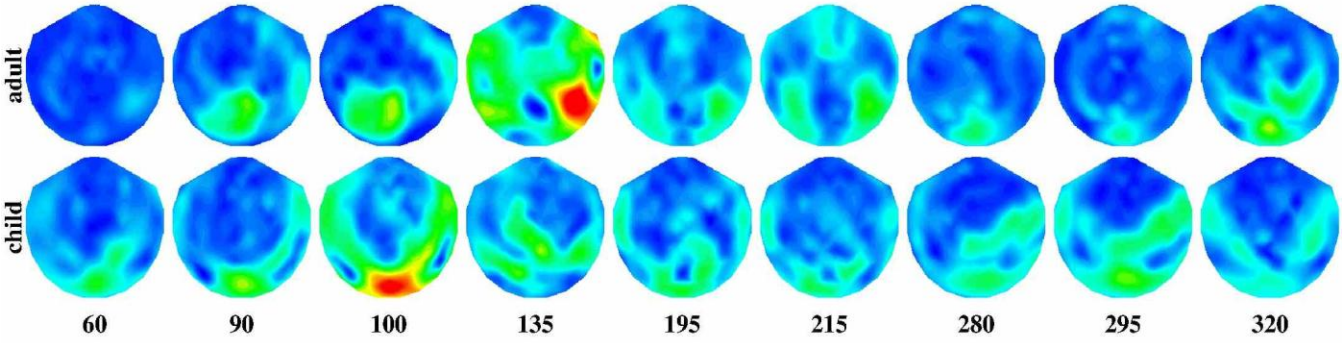
Face responses - control children

Profound differences
in early responses.

140 ms face specific signal
weaker but strong face
signal at 100ms

Autistic children similar but
140 ms even weaker





Conclusions

- Autistic group display very different activity. No evidence that autistic group have developed any significant face specificity

- Even as late as 12 years old, face processing systems are not well established.

The evidence is that people with autism spectrum disorders have developed less specialised neural networks.
This may underlie less 'tuned' social nteractions and awareness.

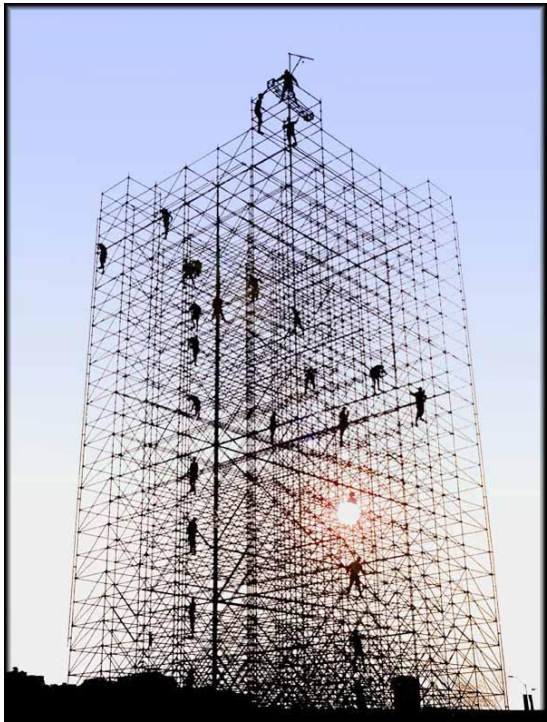
Expertise in algebra

Previous work by Anderson et al. (2008)

fMRI - quasi algebra – data Interpreted using Adaptive Control of Thought – Rational mode

7x+1=29

ENCODE	+1=29	Visual
RETRIEVE	inverse of +1	Retrieve
RETRIEVE	29-1	Retrieve
TRANSFORM	=28	Imaginal
ENCODE	7x	Visual
RETRIEVE	28/7 is 4	Retrieval
TRANSFORM	X=4	Imaginal
KEY	4	Manual



Expertise in algebra

Cognitive tutor

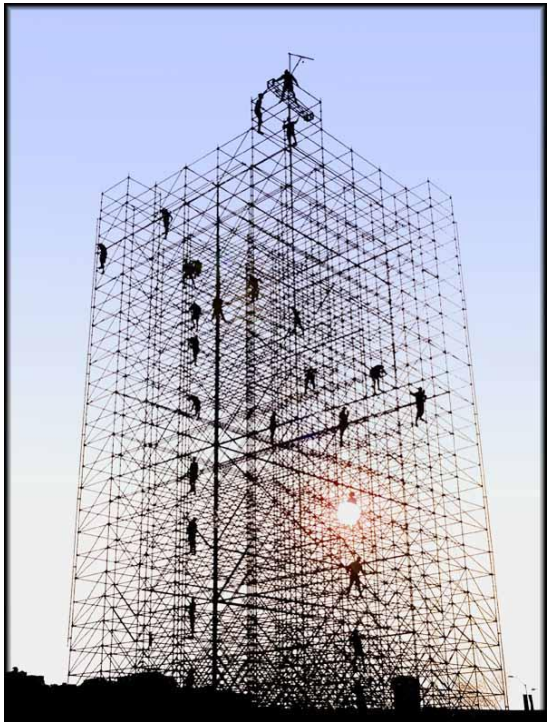
Declarative knowledge of rules of algebra – lateral inferior pre-frontal cortex – study the rules

Perception and recognition of algebraic form

fusiform cortex - practice algebraic reading

Reasoning within the domain of algebra – anterior prefrontal cortex – justify transformations used

MEG can be used longitudinally and can separate out the steps in reasoning



Pilot study

Learning Science strand of work at the new Oxford MEG Centre. (Oxford – OU - Derby)

Centre has a developmental focus

Autism

Algebra

Hypnosis

Arithmetic vs Algebra

Expert vs Naive

The protocol

8 subjects (now 11)

PG students from varying backgrounds

Look at screen

View arithmetic expression or algebraic equation

View 2 solutions

On prompt, choose one and press corresponding button

Repeat (2 time 20 randomised)

6 - 2


3
4

$$4x - 7 = 5$$


2
3

$$5x - 4 = 4x$$


4
6

2 + 3

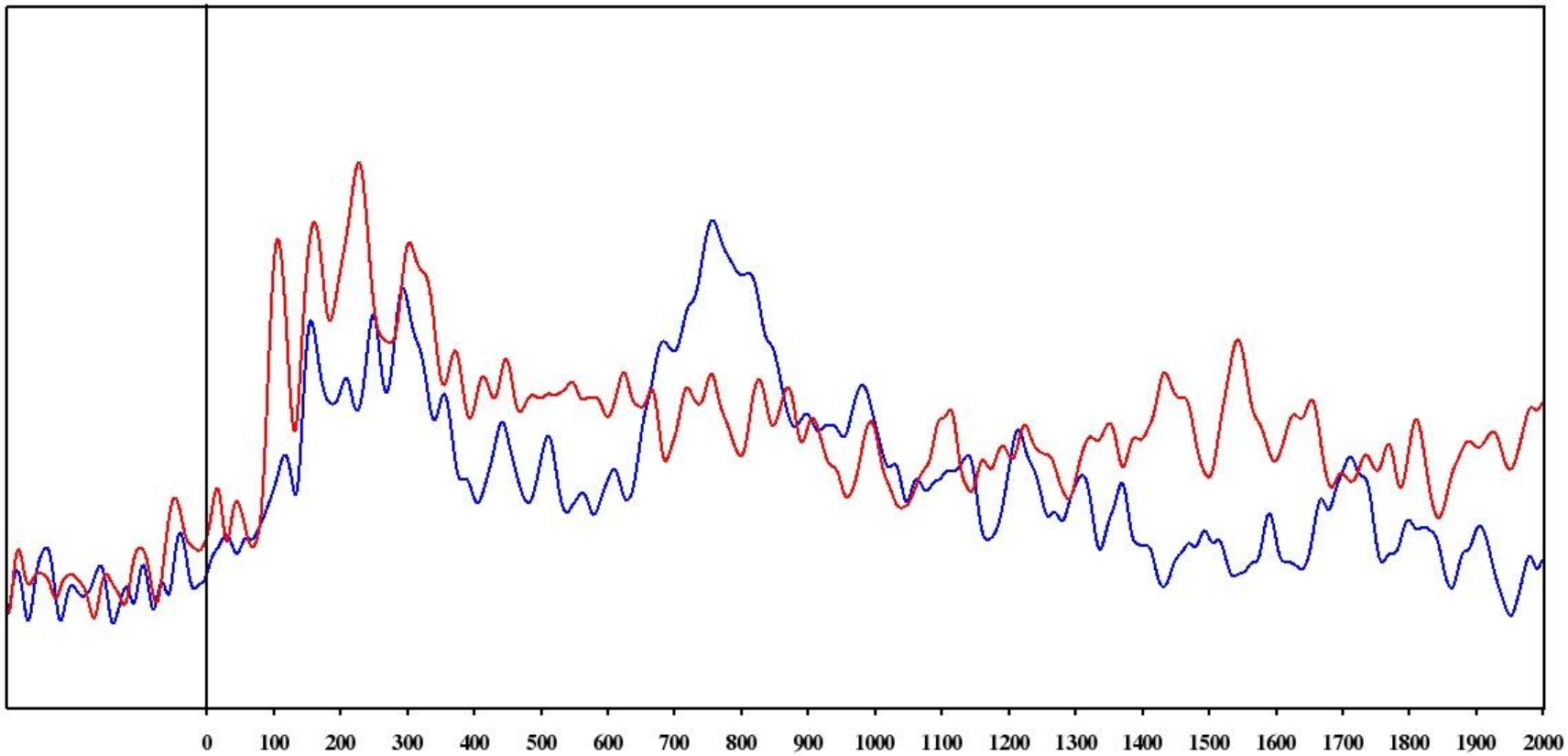

5
6

Results

Behavioural

Algebra correct out of 16 -- 9, 9, 10, 13, 15, 15, 15

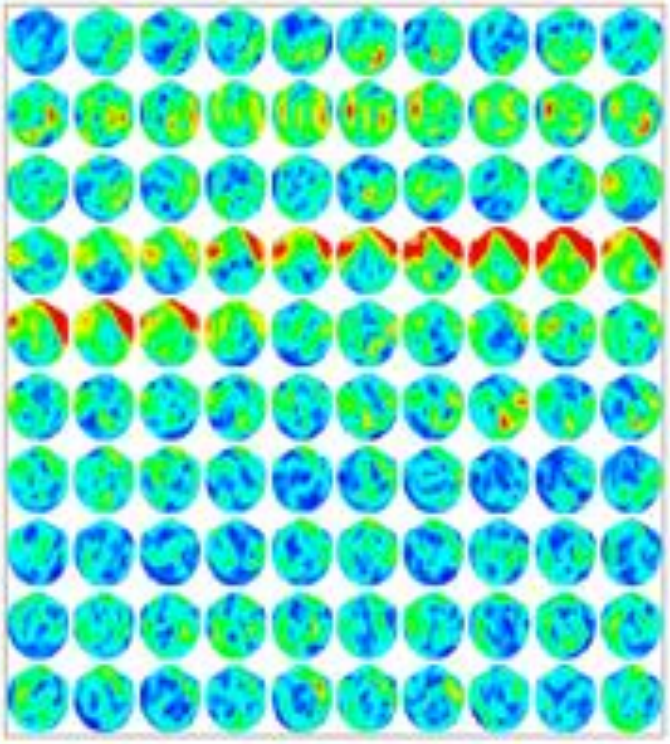
Σ squared signal (all detectors and all subjects in group)



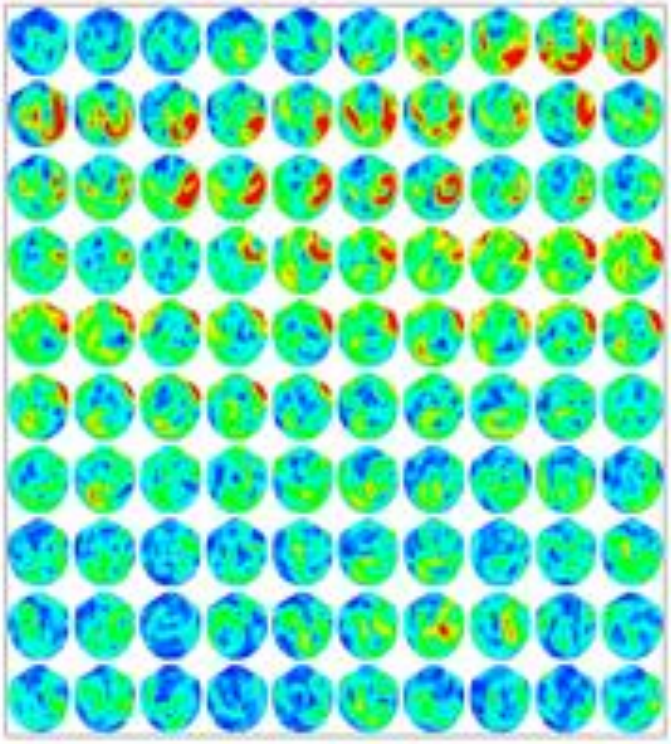
First results

Arithmetic processing

Every 25 ms for 2.5 secs



non expert

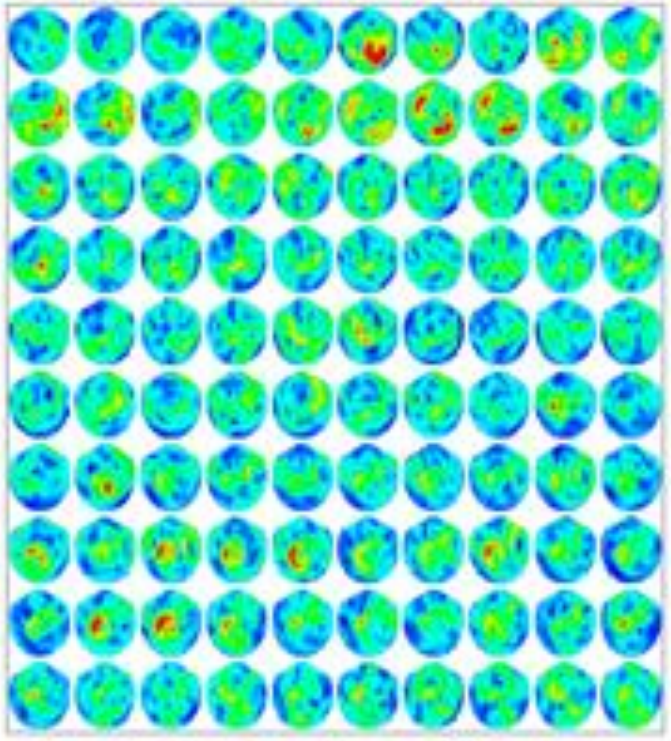


expert

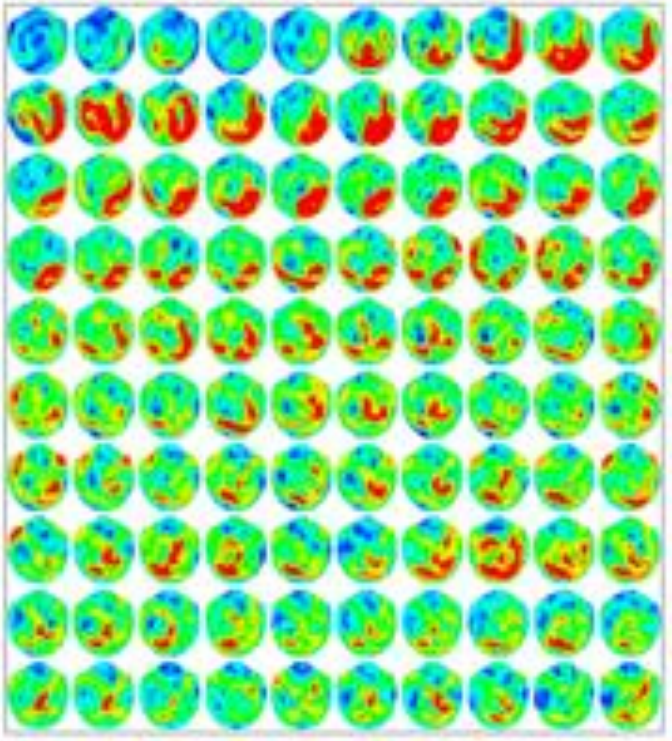
First results

Algebraic processing

Every 25 ms for 2.5 secs



non expert



expert

Interpretation

- Evidence for strong (algebra and arithmetic linked) perceptual processes in experts (fusiform)
- Evidence for declarative arithmetic knowledge retrieval in non experts (inferior frontal at about 0.8 secs)
- Generally greater activity in experts
- Little sign of semantic (language) activity in either group
- Little sign of number relationship processing in either group (parietal cortex)

Next steps

More subjects

Longitudinal study through learning process

Additional protocols (e.g. mechanics problems or chemical structures)

Bright ideas from colleagues

Money

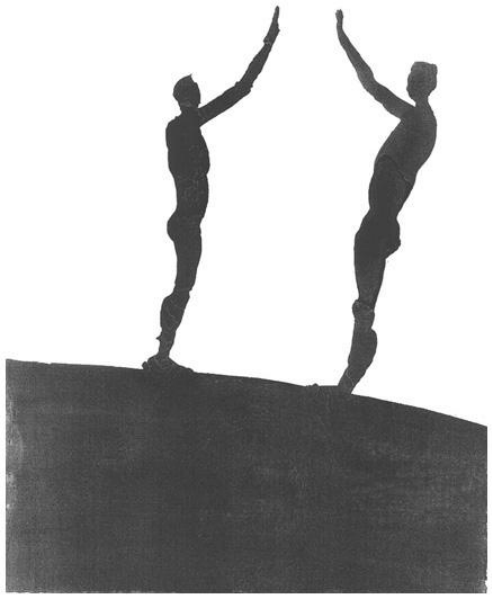
"Can't you ever relax?"

OU CETLs & Science

COLMSCT – communities – peer learning – assessment linked support

πCETL – Physics and astronomy community - access to experiments — online resources and support modules

Examples



Introduction to autism

- Leo Kanner and Hans Asperger -- 1940s – Autism as a childhood disorder of social interaction
- Leo Kanner and Leon Eisenberg – 1955 review - two key features of social aloofness & insistence on sameness
- Mike Rutter – ‘Diagnosis and definition of childhood autism’ – 1978 – language development
- Laura Wing and Judith Gould – Autism Spectrum Disorders ASD – 1979 – Impairments in social, communicative and imaginative development