

# Executive functions: Controlling the learning brain?



Dr Jonathan Sharples  
The Institute for the Future of  
**the mind**

The Institute for the Future of  
**the mind**  
High-quality,  
primary research

**The Young Mind**



Effect of drugs on learning and memory



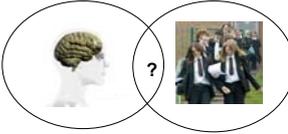
Digital technologies and cognition

**The Ageing Mind**



Identifying a marker for neurodegeneration and a novel mechanism for therapy

The Institute for the Future of  
**the mind**  
Policy and Impact



- How can we apply scientific understandings of learning to develop education policy and practice?
- Identify educational areas where scientific insights can improve pedagogy and policy. Translate between the two fields.

### The Learning Brain



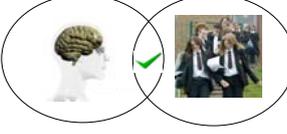
- Literacy
- Nutrition (e.g. omega-3)
- Exercise
- Early-years (0-5yrs)
- Adolescence
- Creativity
- Memory
- Numeracy

- Teachers are the only professionals required to change brain connectivity and structure on a daily basis!



- In a survey of teachers attending in-service training, 90% thought that a knowledge of the brain was important, or very important, in the design and delivery of teaching.

Pickering, S and Howard-Jones, P. (2007)




**The School of Accelerated Learning**

**Left Brain Learning**

**Accelerated Learning**

**ernativity**

The Institute for the Future of the mind  
 Gloucestershire  
 the mind

### "Science of Learning" pilot-project



Science insights on learning      Teachers' practical expertise

??

The Institute for the Future of the mind  
 Gloucestershire  
 the mind

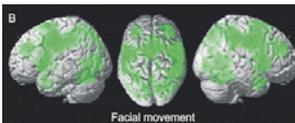
### "Science of Learning" pilot-project

- How can engaging teachers with scientific ideas on learning develop classroom practice?
- 20 teachers - mixed subject and primary/secondary
- Series of workshops from neuroscientists and psychologists on different aspects of cognition
- Support them in integrating this knowledge into practice.

e.g.

- Numeracy
- Memory
- Creativity
- Adolescence

### Brains are made for moving



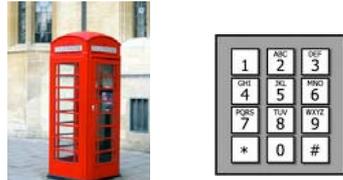
Facial movement

- Motor (movement) systems make up large parts of the brain
- evolutionarily advanced systems

- Recruit motor networks into learning - help deepen representation of concepts

↓

better chance of it being strongly laid down in memory



- Easier to remember a number with a movement

↓

Incorporates motor networks

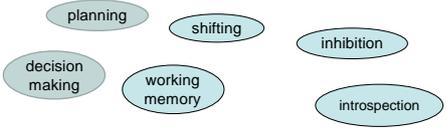
### TLRP 'Principles into Practice' (2007) -

"In order to develop children as reflective learners, teachers first have to develop this disposition for themselves...."

*"The project has got me out of the rut to deliver quick-fix strategies to deliver the usual learning objectives. This has me questioning, is this appropriate? are they learning? The positive feedback I have received has reinforced this shift in practice"*

### Executive Function (EF)

- Aspects of our relating to how we **control** our thoughts and actions in order to respond flexibly to changes in the environment.
- Used in novel situations or when you have to do something different to normal - **organise** our thinking
- Includes a number of different processes:



### Executive Function - doing the weekly shop



Remember a shopping list  
working memory

One list for you, one for your mother  
shifting

Plan your route around the shop  
planning

Stop yourself from buying your favourite chocolate  
inhibition

Do I buy the organic chicken, even though it's more expensive?  
decision making



### Executive Function - pupils in the classroom

plan your experiment  
planning

switch between getting on with your work and listening to the teacher  
shifting

stop yourself from being distracted by others  
inhibition

remember what you're supposed to be doing  
working memory

do I work harder now or leave it for homework later?  
decision making




### Frontal Lobes - role in executive function



Frontal lobes (Prefrontal cortex)

- **most interconnected region of the brain** - all other parts of the brain (sensory, motor, automatic emotions)
- well-designed for its coordinating roles - 1. Integrating diverse representations 2. Exerting control over systems

Two types of mental processes taking place in the brain at the same time:

#### Controlled (EF)

Thinking that takes effort  
- centre stage

One at a time

Novel responses

More frontal lobes  
e.g. planning a journey

#### Automatic

Thinking that happens without conscious control

In parallel

Well-rehearsed (routine)

All over the brain  
e.g. steering, braking, reading the road

Impossible to keep track of everything - most mental processes happens automatically

### A quick language test!

Aim: Create four-word sentences

1. him was worried she always
2. from are Florida oranges temperature
3. ball the throw toss silently
4. shoes give replace old the
5. sky the seamless grey is
6. sunlight makes temperature wrinkle grapes.

### Primed for action

1. him was **worried** she always
2. from are **Florida** oranges temperature
3. ball the throw toss **silently**
4. shoes give replace **old** the
5. sky the seamless **grey** is
6. sunlight makes temperature **wrinkle** grapes.

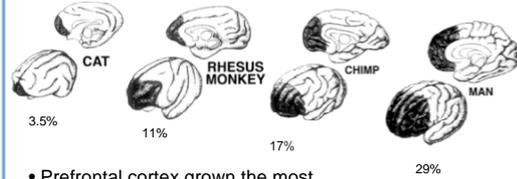
Automatic processing thinks about 'old' → Walk slower after the test!

Automatic processing plays a big part in decisions



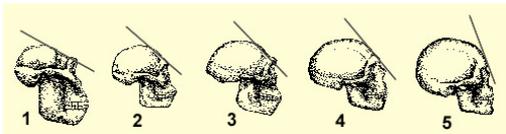
### Evolution of frontal lobes

- Brain has expanded forward at a huge rate!



- Prefrontal cortex grown the most
- Also denser interconnections to other brain regions - *freed us from responding to the immediate situation*

### Forehead change in humans



1. *Australopithecus robustus* 2. *Homo habilis* 3. *Homo erectus* 4. *Homo sapiens neanderthalensis* 5. *Homo sapiens sapiens*

### automatic processes

- drive for food/sex, reacting to danger, moving, sensing etc



100's million years

### controlled processes

- conscious planning, reasoning, logical thinking, language



new kid on the block!

### Executive Function - The brain's 'bouncer'?



or



?!

### Brain - 'Elephant and rider'



Rider = controlled conscious thinking (EF)

Elephant = automatic processing

### Executive functions and learning

Children's ability to control attention and action are stronger predictors of academic performance than is IQ or entry-level maths or reading skills.

Blair, C. (2003)

Primary school teachers rank Executive Functions as the most important characteristic necessary for school readiness and indicate that over half their children lack effective EF.

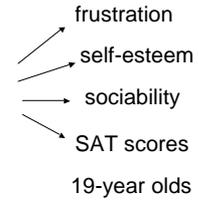
Rimm-Kaufman et al. (2000)



Walter Mischel - Classic 'Marshmallow Experiment'  
Importance of self-control



4-year olds



19-year olds

Mischel, W. et al (1989). *Science*, 244, 933-938

### Educational Domains

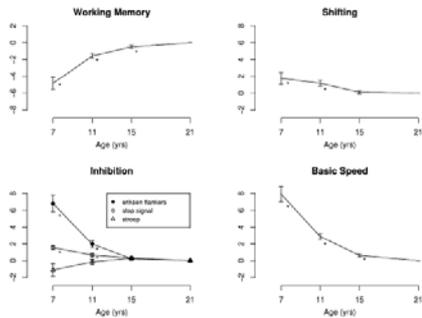


Blair, C. (2003) *Dev Psychobiol.* 42(3) p301

Can we help young children develop these critical executive function/self-regulation abilities?



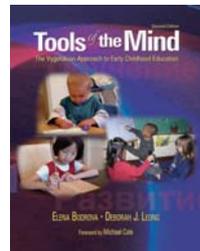
### Executive function development



Huizinga, Dolan, & van der Molen (2006) *Neuropsychologia*

### Tools of the Mind - preschool programme

• A US-based preschool curriculum that improves Executive Functions



• based on the idea that teaching social, emotional and cognitive self-regulation is as important as teaching academic skills

• training is embedded in all aspects of the school day



### Tools of the Mind - Curriculum

- Core of 40 activities to promote EF and self-regulation



'Buddy reading' - improve attention and listening/self-regulation



Strong emphasis on intentional, make-believe play:

- remembering role (WM),
- inhibit acting out of character
- adjust to the evolving plot (cognitive flexibility)

### THE EARLY YEARS

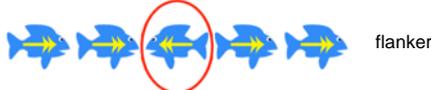
## Preschool Program Improves Cognitive Control

*Adele Diamond, W. Steven Barnett, Jessica Thomas, Sarah Munro*

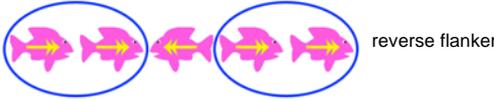
- Randomised control trial of Tools of the Mind programme
- 20 classes in a low-income district in New Jersey
- Half assigned randomly to Tools of Mind, half on normal curriculum
- Comparable abilities at the start. Progress followed for two years
- Tested independently on two standard measures of EF
- Academic scores of Tools of the Mind schools also followed

Diamond et al. (2007) *Science*, 318

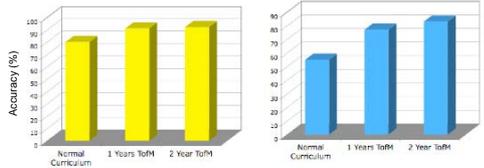
### Test of Executive Function - Flanker test



Inhibit influence of flanker fishes



Inhibit influence of flanker fishes + remember new rule



Flanker task - 10-15% improvement on Tools of Mind

Reverse Flanker - 20-30% improvement on Tools of Mind

- Tools of Mind children met or exceeded all state and national standards for preschoolers in literacy and maths

### Tools of the Mind -Conclusions

- EF skills are not fixed, even in very young children
- EF skills can be improved in preschoolers in regular classrooms by regular teachers, without expensive equipment or 1:1 attention
- Expect benefits from early EF-training to increase over time
- Tools of the Mind was named an exemplary innovation by the International Bureau of Education at UNESCO in 2001 - only one in US at the time
- Website: [www.toolsofthemind.org/](http://www.toolsofthemind.org/)

### Training the elephant - Improve 'Metacognition'

- Adults are more aware of their thinking - introspection
- They tend to evaluate a task and work out the best strategy to make it easier
  - Work through things systematically
  - Use internal speech
- Children seem less likely to do this
- Is this an area where executive functions can be improved?



Entity view  
Fixed mindset - pre-determined



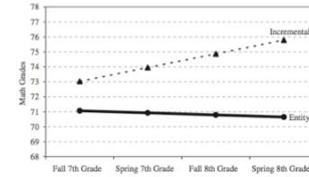
Incremental view  
Growth mindset - potential through effort

### Fixed vs Growth mindsets



intelligence

- Fixed mindset - less motivated to learn, less resilient
- Growth mindset - more motivated and resilient



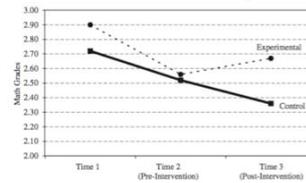
Blackwell et al (2007) Child Development, 78(1) p246



“Success is the ability to go from one failure to another with no loss of enthusiasm.”

### ‘Brainology’

- Illustrate the flexible nature of intelligence through an awareness of brain plasticity:
  - learning changes brain connectivity
  - this process continues through life
  - you are in charge of that process
- 8 x 1/2hr intervention lessons - change mindset, motivation and grades



Primary/Secondary transition

Blackwell et al (2007) Child Development, 78(1) p246

“Study and learning skills are inert until powered by motivation”

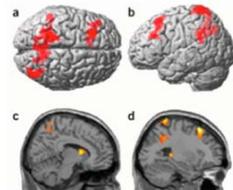
Carol Dweck

- improving metacognitive awareness of learning (improving EF) can help light the fire!



### Breaking news!

Working memory training increased brain activity related to working memory in the frontal and parietal cortices (in adults - 45min a day/5 weeks)

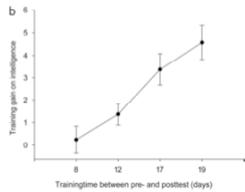


So what?!...

Olesen, Westerberg, & Klingberg (2003) Nature Neuroscience

### WM training improves fluid intelligence

- WM training improves **'fluid intelligence'**
- Fluid intelligence: Reasoning and problem solving requiring no prior knowledge (i.e. mental horsepower)
- Closely linked to academic and professional success



Jaeggi (2008) 105(19) Science

### SUMMING UP

- Executive functions are central to our day-to-day function and learning
- Executive functions begin developing at a young age and continue through our lives
- Executive functions *CAN* be improved through education - explicitly and by developing an awareness of children's own thinking/behaviour
- As educators we should actively seek opportunities to train the elephant!

Thank you!



The Institute for the Future of  
the mind