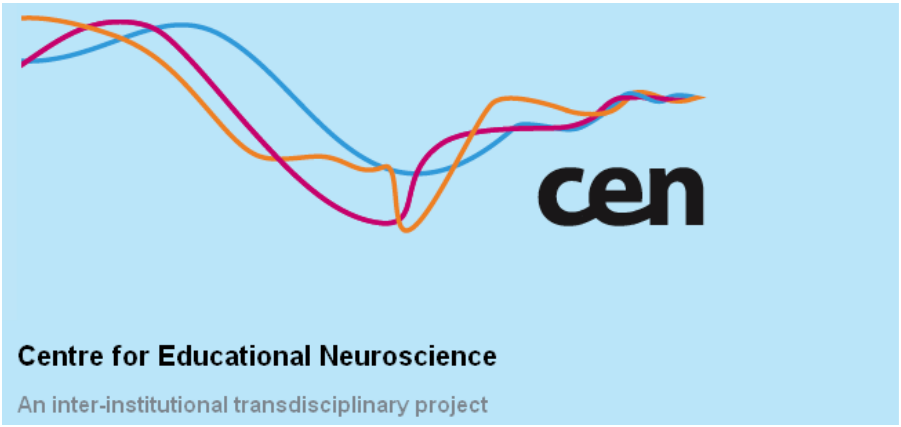
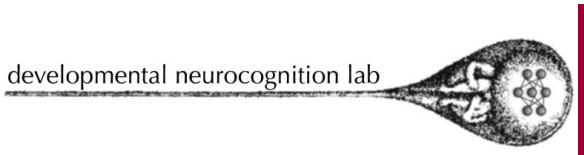




Sensitive periods in brain development and their relation to education

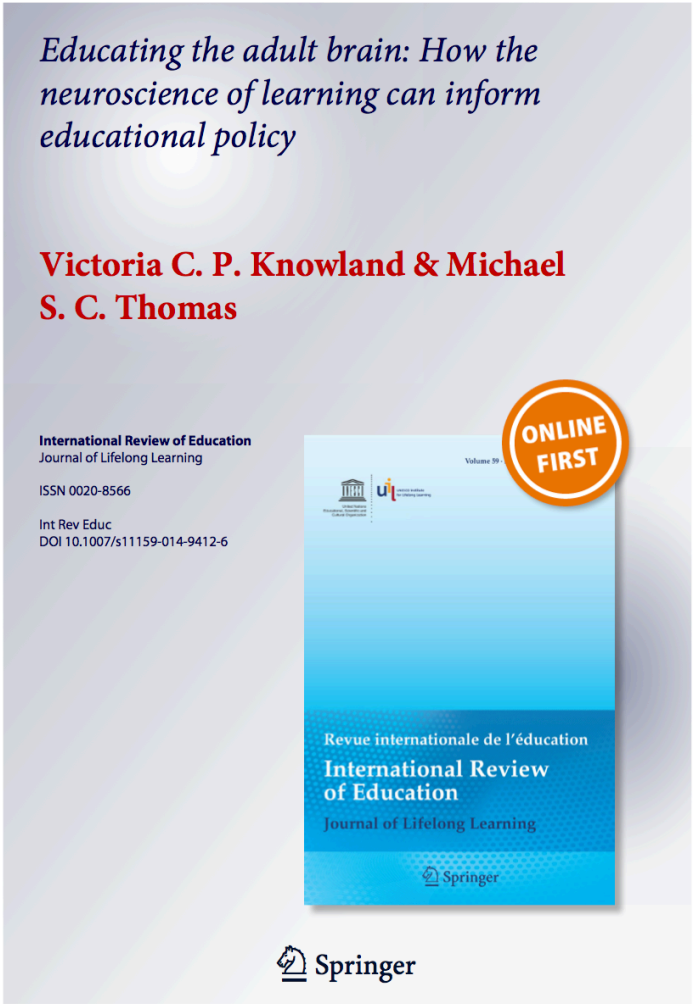
Michael S. C. Thomas
Director, CEN

21 October 2014

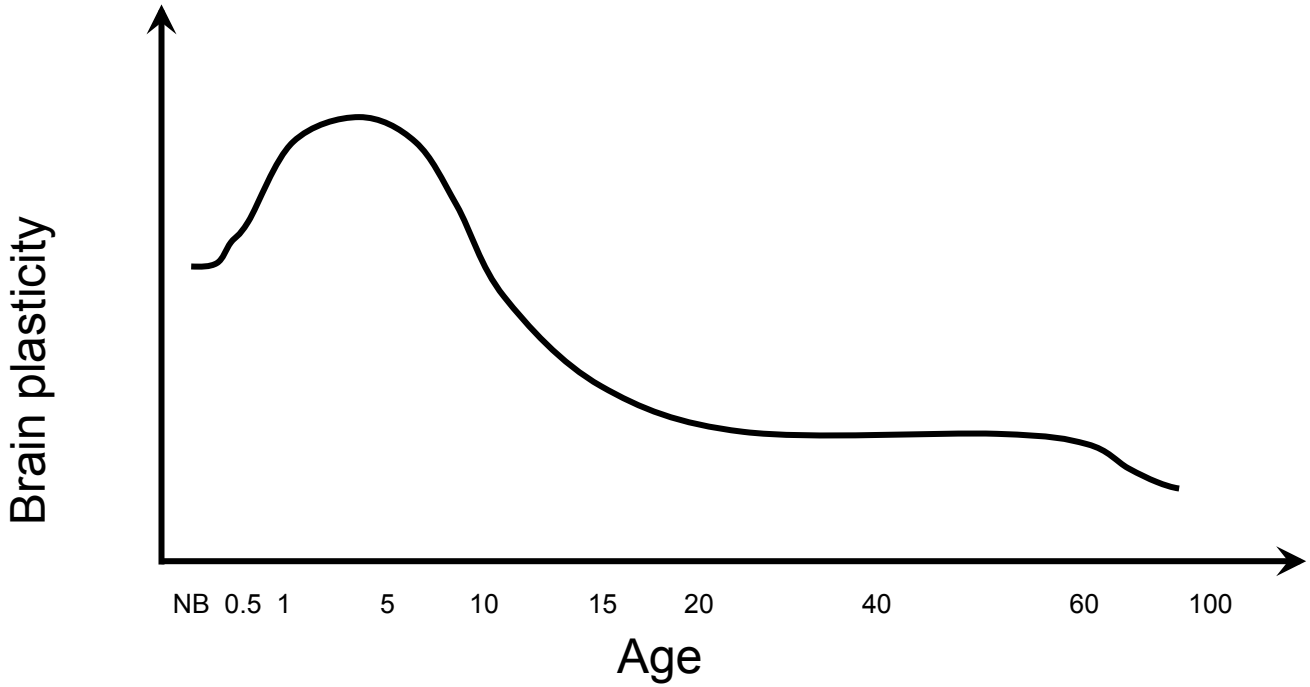
Does the brain's plasticity reduce with age?

- World Bank:
  - "Adult literacy is an important route to escape poverty in developing countries. But literacy programs aren't that successful. Are there any sensitive periods in reading acquisition that would hinder adult learners? How could they be overcome?"

Centre for Educational Neuroscience



The Function linking Plasticity and Age



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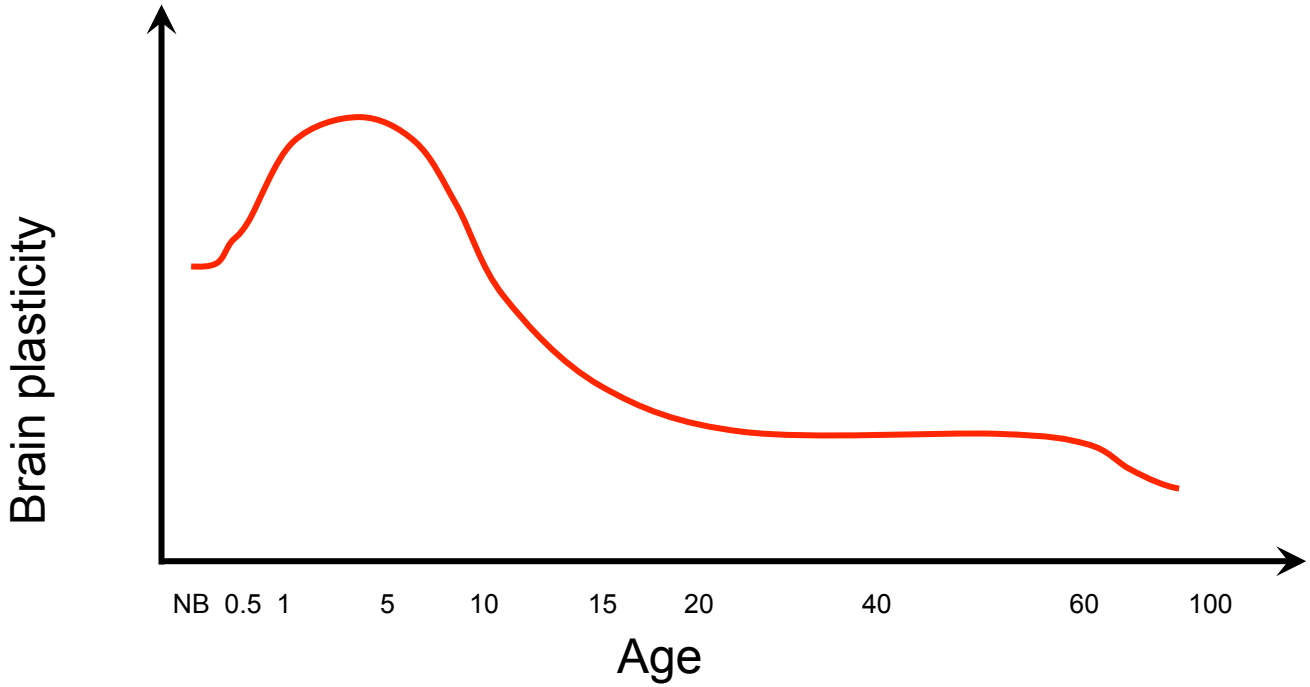

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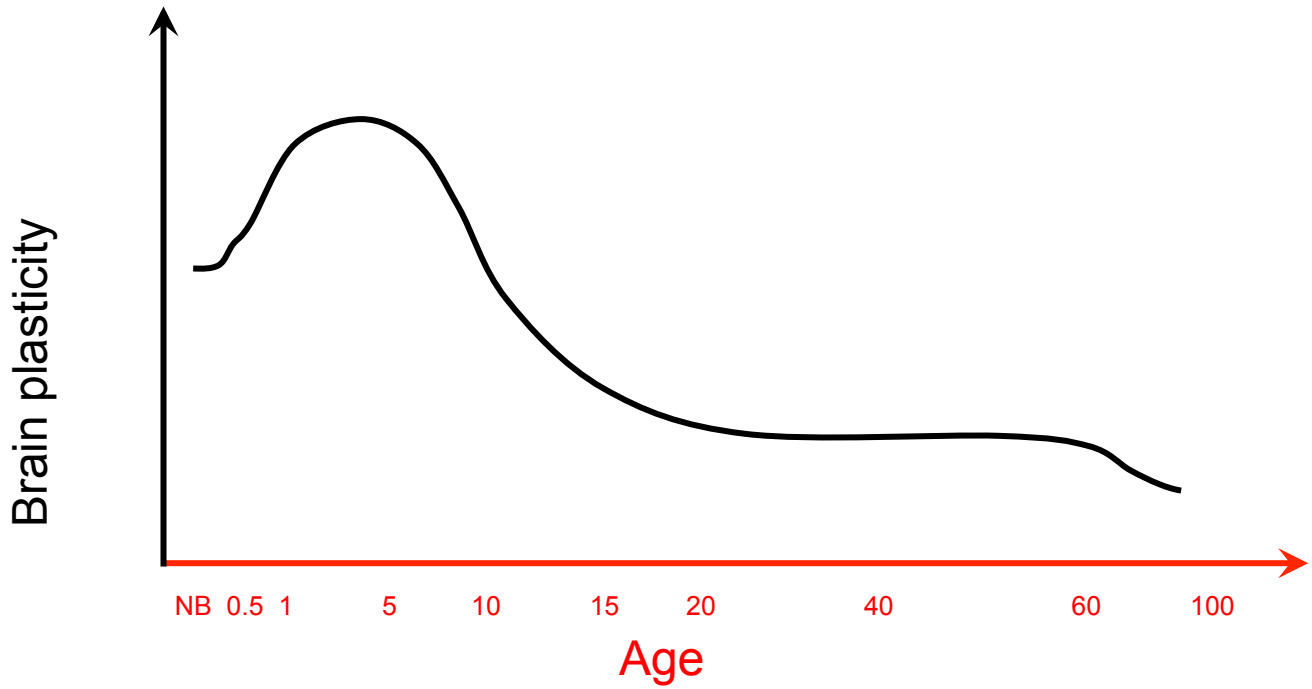
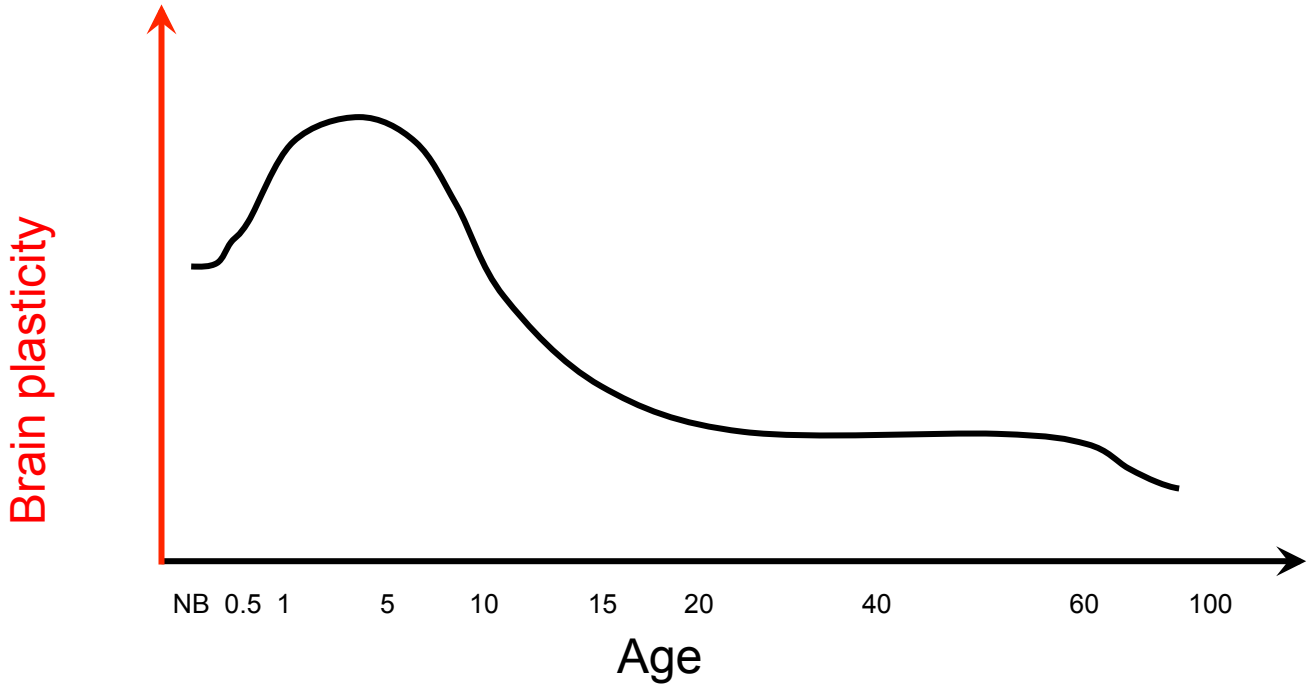
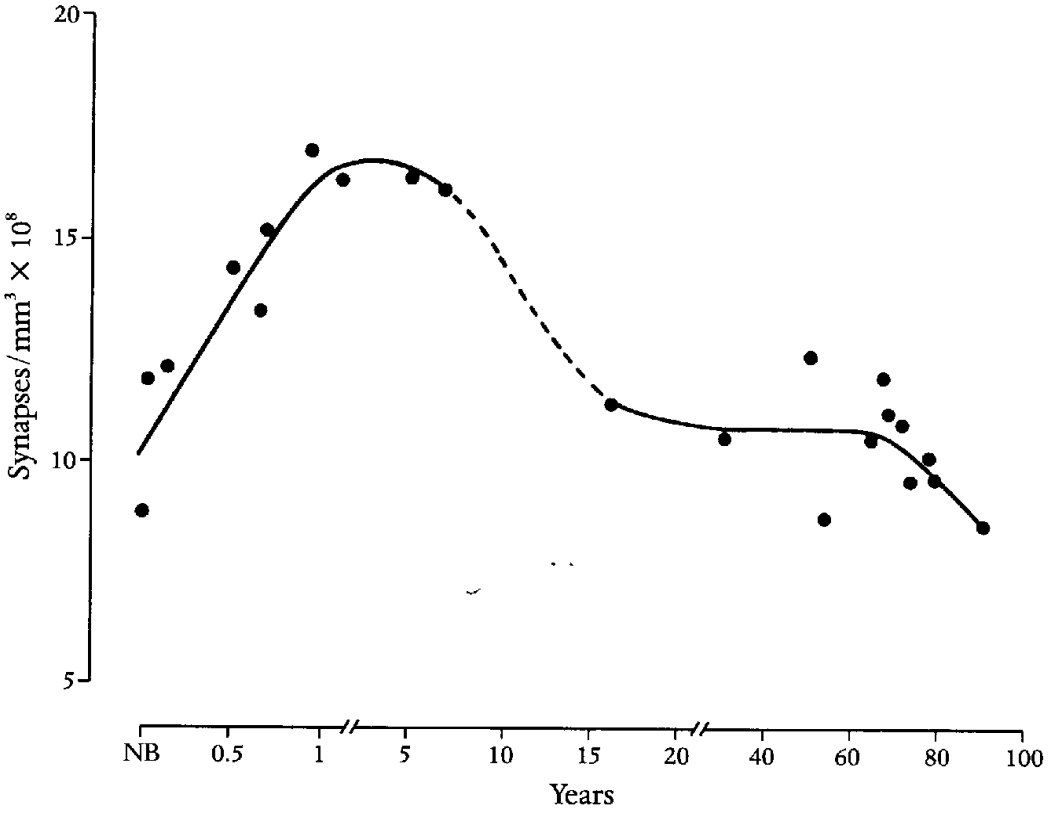
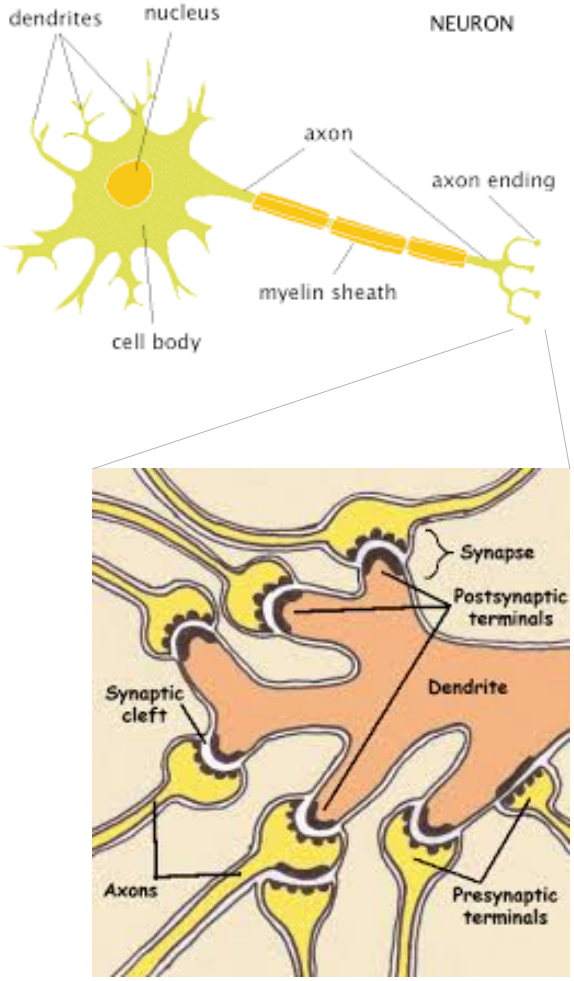


The Function linking Plasticity and Age



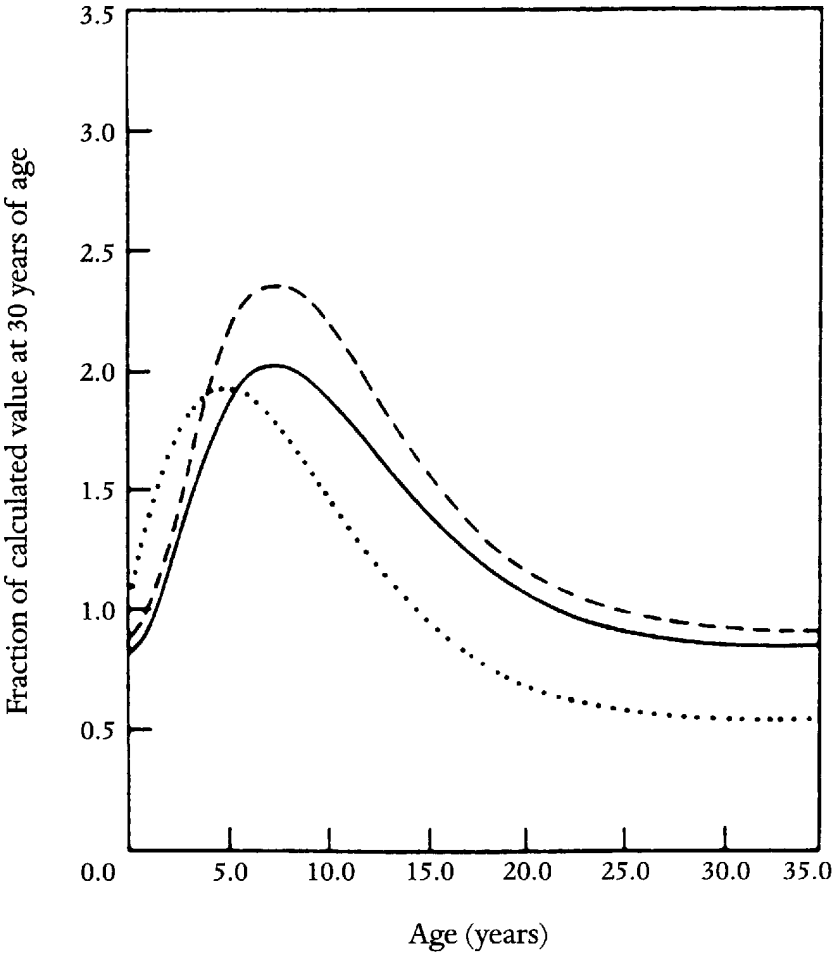
Synaptic density in prefrontal cortex (middle frontal gyrus)





Huttenlocher (2001)

Feinberg et al. (1990)



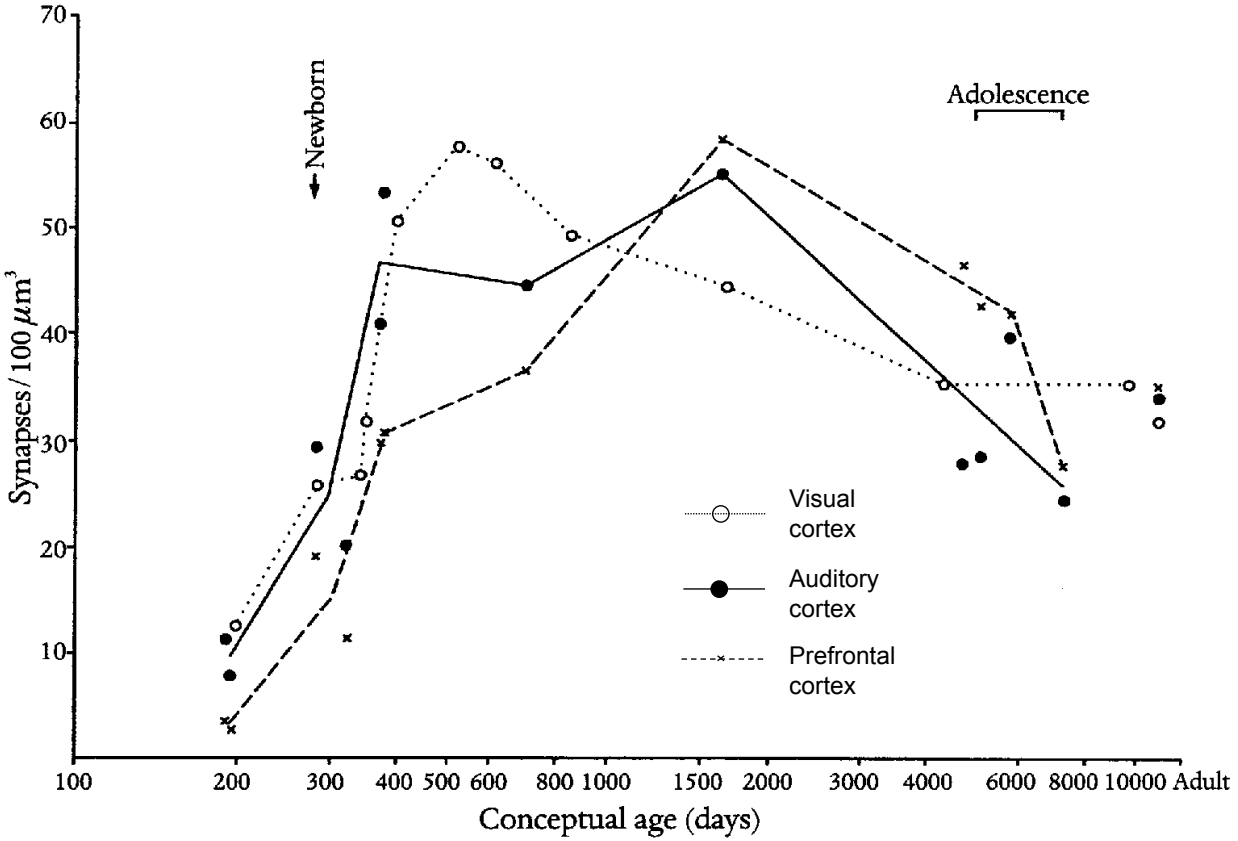
Synaptic density squared

Delta wave amplitude (EEG)

Cortical metabolic rate

Data standardised to the value at 30 years of age

No single ‘plasticity’?



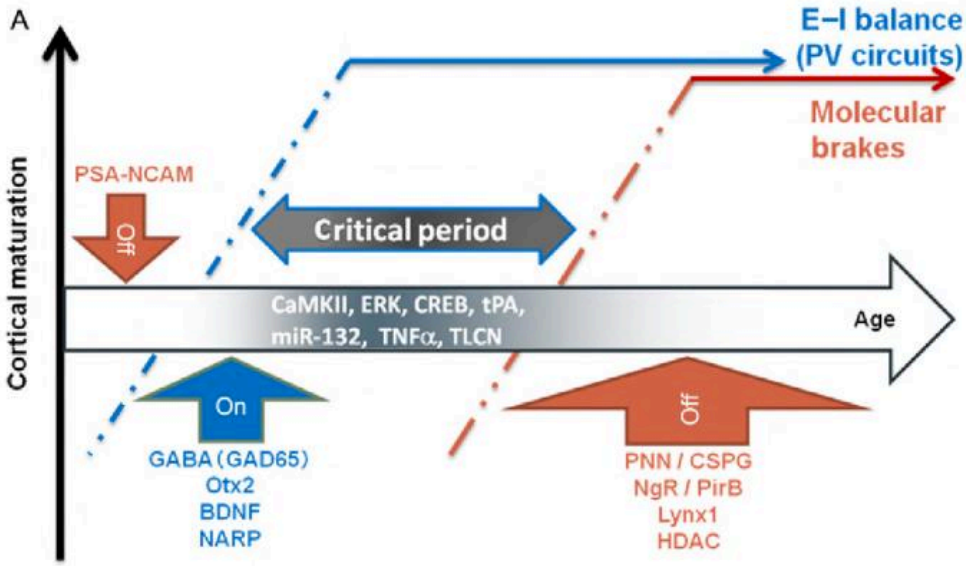
Huttenlocher (2001)

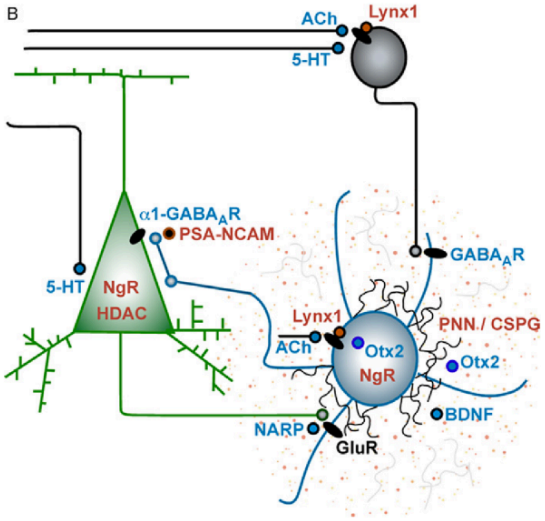
Diverse behavioural data on sensitive periods

- Skill acquisition
  - got to start early for expertise
  - videogame playing
  - musical instruments
- Age of acquisition effects
  - early acquired vocabulary most robust
- Acquisition of a second language
  - e.g., non-native phonemes; immersion vs. interleaving
- Somatosensory and motor plasticity
  - e.g., violinists and acquired paralysis; phantom limbs
- Rehabilitation of limb paralysis after stroke
- Recovery of cognitive abilities after brain damage at different ages
  - e.g., language
- Deprivation
  - e.g., of language input, of sensory input, amblyopia

HOW MANY DIFFERENT MECHANISMS?

Takesian & Hensch (2013)





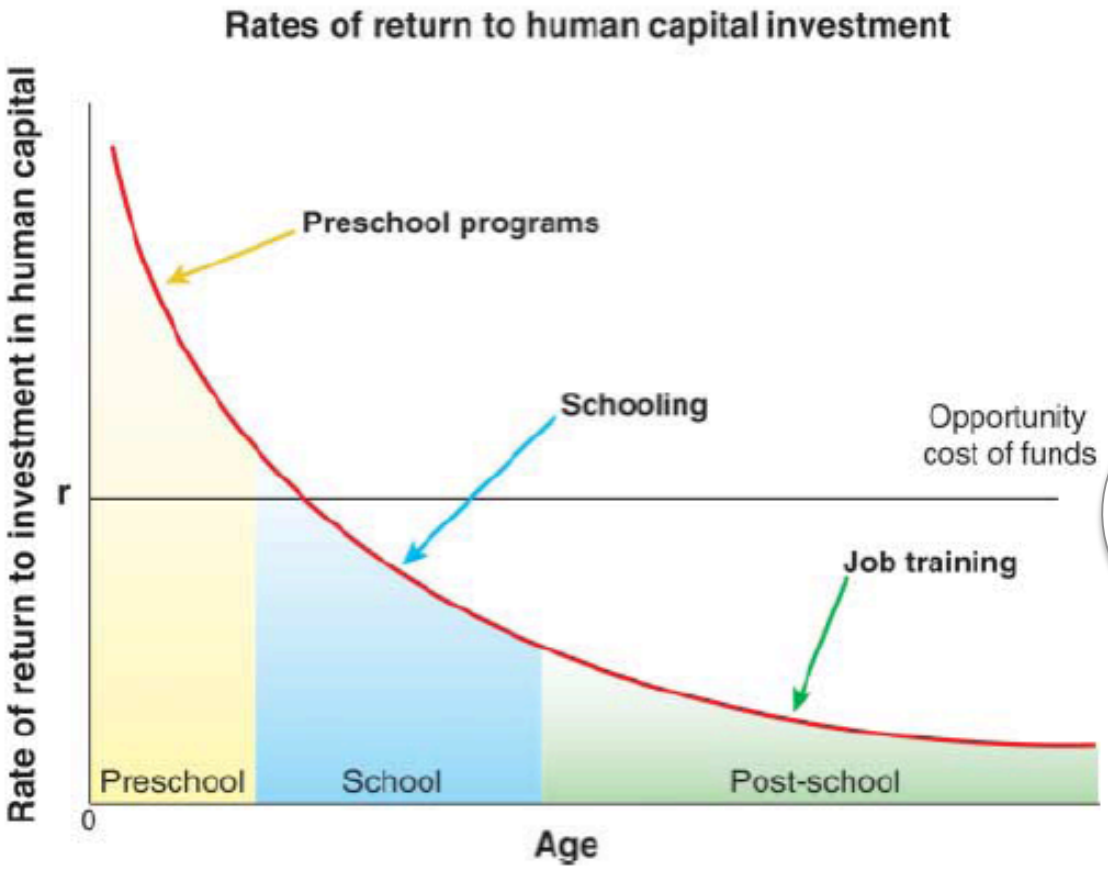
Takesian, AE, Kensch, TK (2013).Balancing plasticity/stability across brain development. Prog Brain Res. 2013;207:3-34

Implications for high-level cognition and education?

- Takesian & Hensch (2013):
  - "While strict limitations on plasticity may be evident in primary sensory areas, they gradually become less rigid in higher cognitive domains … the cellular and molecular constraints that are present at earlier stages [in the hierarchy] seem to be loosened or absent."

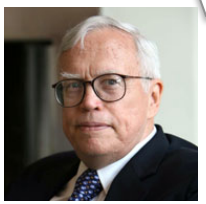
Arguments for early intervention in education

- Economist James Heckman and colleagues



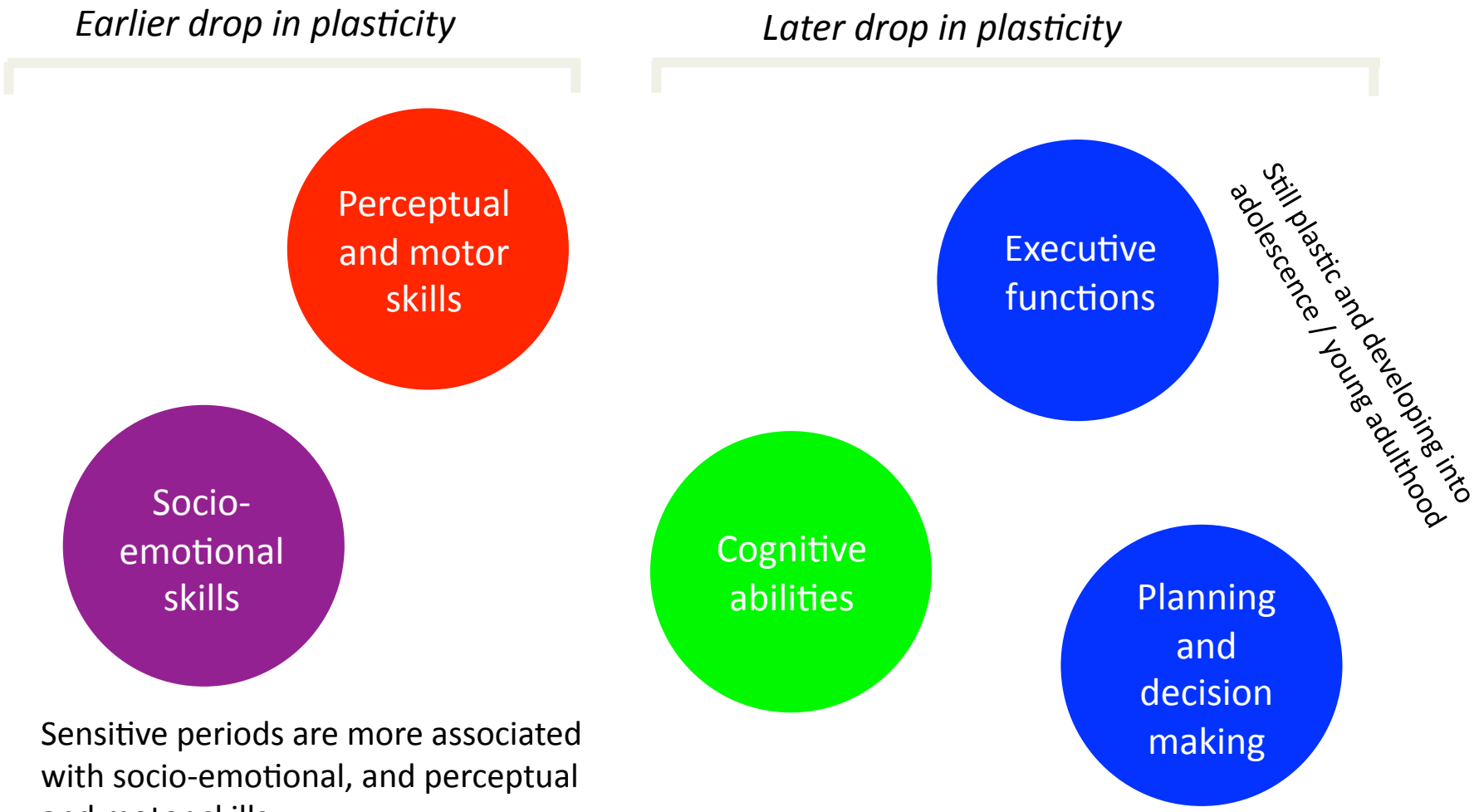
- Invest in early intervention to help disadvantaged children

There is compelling evidence of critical and sensitive periods in development . . . Different types of abilities appear to be manipulable at different ages. IQ scores become stable by age 10 or so, suggesting a sensitive period for their formation below age 10



levels of spending. The opportunity cost of funds (r) is the payout per year if the dollar is invested in financial assets (e.g., passbook savings) instead. An optimal

Different profiles of plasticity for different abilities



Sensitive periods are more associated with socio-emotional, and perceptual and motor skills

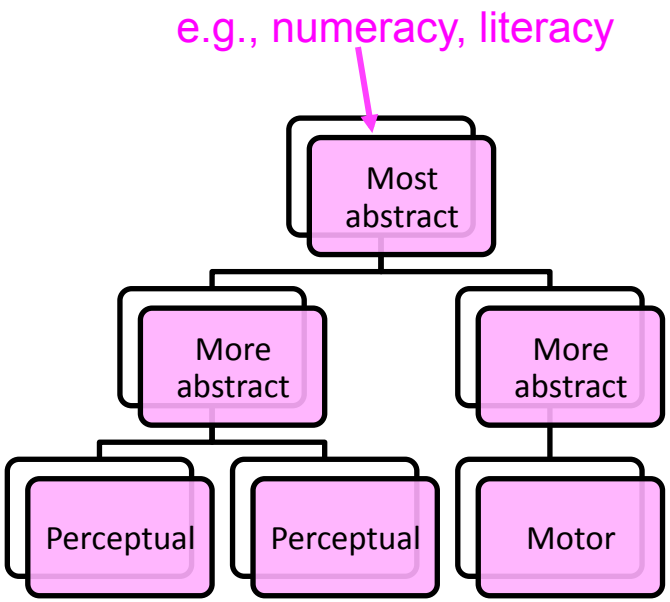
Intervene early

=

Start education early

?

A hierarchy of systems



Sensitive periods here >>>

<<< Sensitive periods here

Education relevant behaviours represent the interaction of many brain areas

Thomas & Knowland (2009)

- ‘An educational curriculum would be optimised if the age at which each academic subject or skill was taught coincided with the period of maximum plasticity for the brain systems involved’

- But …
  - Age may not be the same if experience affects plasticity
  - High-level skills integrate across many systems with potentially different sensitive periods

Sensitive periods and education

- Late learned complex behaviours may be restricted by a reduction in perceptual / motor plasticity
- Learn these skills early for best ultimate proficiency
  - Learning multiple languages
  - Musician
  - Gymnast

A change in learning style with age

Adolescence is midway between the two

Child Learner	Adult learner
Exploration	Intense training
Many tasks at once	Cease interfering tasks
Natural exposure to task	Exaggerate key dimensions of task
Fewer cognitive resources required	More cognitive resources required
Attention	Attention + *motivation*
Implicit learning, extract trends from lots of data (less sensitive to feedback)	Use of strategies, rely on explicit rules (sensitive to feedback)
Social context enhances learning	Social context enhances learning

Thomas (2012)

Sensitive periods and education: ever too early to learn?

- Sequence is more important than timing, since more abstract / complex skills are built on a foundation of simpler ones
- Compare best age to learn:
  - (1) a foreign language
  - (2) the philosophy of Descartes

- Skills related to the control of behaviour may
  - (a) depend on later developing brain regions
  - (b) may only be relevant in later years (e.g., self-regulation, risk-taking)

Conclusions

- Education: Are there sensitive periods after which children's learning abilities decline?

- Yes for perceptual skills
  - Get visual / auditory problems fixed early
- No for abilities relevant to educational curriculum
  - It's never too late but all things being equal earlier is better (linear decline in the ultimate level of proficiency that can be achieved)

Conclusions

- Present:
  - No such thing as the brain's plasticity
    - A range of phenomena
    - A range of mechanisms
  - Hierarchy of systems, most plastic at the top
  - Education targets top
    - Relevant sensori-motor systems need to be okay
    - Socio-emotional development needs to be okay

- Future
  - Individual differences in plasticity and IQ?
  - Removing the brakes on plasticity: can plasticity be enhanced?
    - Interfere with stability-plasticity trade-off at your peril?
    - Direct brain stimulation as example of sci-fi future?
  - When functional plasticity reduces, mechanisms responsible will determine intervention to improve behaviour

Mail Online Science & Tech

Can you supercharge your brain by zapping it with electricity? US Military tech being used by hackers to try and boost their brainpower

- **Claims applying small amount of electricity could take away pain, help memory and improve attention**
- **Hackers have created their own $25 hardware to administer shocks**

By MARK PRIGG

PUBLISHED: 23:13, 4 June 2014 | **UPDATED:** 07:55, 5 June 2014

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Applying mild electrical currents to your head could take away pain, help memory and improve attention, it has been claimed.

The technique, called transcranial direct-current stimulation (TDCS) has led to an explosion in hackers attempting to try the technique for themselves.

It has proved so successful even the US military has funded work into it.

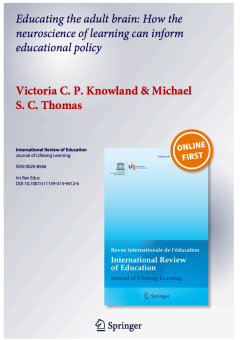
The $250 foc.us headset zaps the brain with electricity, and claims to be able to increase the plasticity and make synapses fire faster.

This $350 headset can increase the plasticity of your brain and make the synapses fire faster

Thanks for your attention!

- Acknowledgements
  - Victoria Knowland
  - Mark Johnson
  - Annette Karmiloff-Smith
  - Cathy Price
  - Helen Abadzi
  - Fiona Richardson
  - Neil Forrester
  - Funders: MRC, ESRC, Leverhulme

Knowland & Thomas (2014)



- Neurobiological principles of adult learning:
  1. Practice is crucial to achieve automaticity over competency
  2. Motivation and attention to stimuli necessary. Feedback may be particularly important for older adults
  3. Learning from a live tutor and actively engaging with materials more important for adults than for children
  4. Order in which elements of a skill are taught is important consideration in curriculum development: fundamental skills support higher abilities
  5. The learning environment should be as free from noise as possible
  6. When learning a new distinction, materials should initially exaggerate relevant perceptual features. Combine with intermittent practice
  7. Get a good night's sleep to consolidate learn

- Questions requiring more research:
  - Can adults achieve the same level of auto And if so, under what conditions?
  - Are there low-level skills which limit complex skill acquisit s literacy, in adulthood?
  - Can training attention control result in more effective and efficient learning across domains in older adults?

1. Large perceptual span
2. Attend to fine perceptual details to discriminate letters while ignoring gross differences (font, handwriting style)
3. Fine rapid control of eye movements
4. Rapid speed of visual processing

Can plasticity be enhanced?

- Behavioural techniques to optimise learning in humans
  - Properties of training (difficulty, motivation, feedback)
  - Generality of effects
    - mostly specific
    - general improvement from action video games, musical training, athletic training, aerobics, meditation
- Molecular studies of learning in animals
  - 'Brakes' on plasticity
    - Structural (myelination, local connectivity changes)
    - Functional (balance of excitation vs. inhibition)

Bavelier and colleagues (2008, 2010)