The Learning Brain

Summer 2011

Introduction

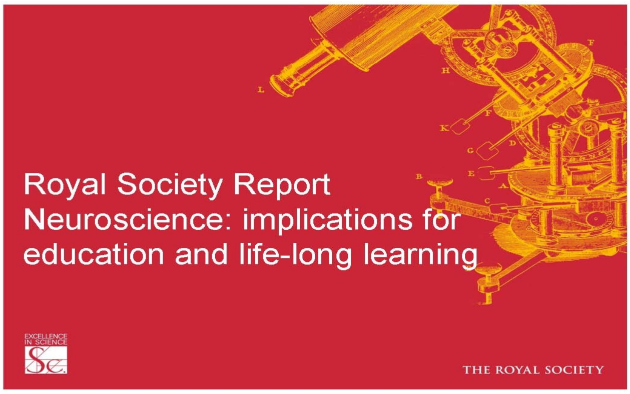
Dr. Bob Stephenson Eton College

This short booklet is designed to give an overview of the keynote and breakout sessions on this topic at the conference.

During the past decade advances in neurobiological techniques, particularly noninvasive ways of evaluating activity in human brains, has precipitated an explosion of research into all aspects of cognition. Whereas, in the past, we were largely dependent upon the analysis of patients exhibiting neural trauma to explore the complexities of motivation, leaning and memory today this can be done with normal subjects, in real time (with some limitations) and on relatively large samples.

These techniques, recording discrete electrical activity (electroencephalography EEG and magnetoencephalography MEG), regional cerebral blood flow (blood flow to the most active regions), specific binding of particular drugs and neurotransmitters (positron emission tomography (PET) and functional magnetic resonance imaging, have been instrumental in allowing scientists to probe complex processes. It has even been possible, using transcranial magnetic stimulation (TMS), to temporarily disrupt activity in specific areas to test a hypothesis. These functional techniques associated with tensor imaging and structural magnetic resonance imaging are revealing a huge amount of useful information.

However, this work cannot go on in a vacuum and like all great scientific developments it is dependent upon careful observation and the collection of huge amounts of corroborative data to have any credence. From the outset this has been the Intention of the Royal Society and its working parties in the Brain Waves Project.



The new field of 'educational neuroscience' sometimes called 'neuroeducation', investigates some of the basic processes involved in learning to become literate and numerate; but beyond this it also explores 'learning to learn', cognitive control and flexibility, motivation as well as social and emo-

With the effective engagement of all learners as well as teachers, parents and policy makers, the impact of this emerging discipline could be highly beneficial" (Frith 2011).

Hopefully we can as an organisation contribute to this debate.

Between Euphoria and Rejection

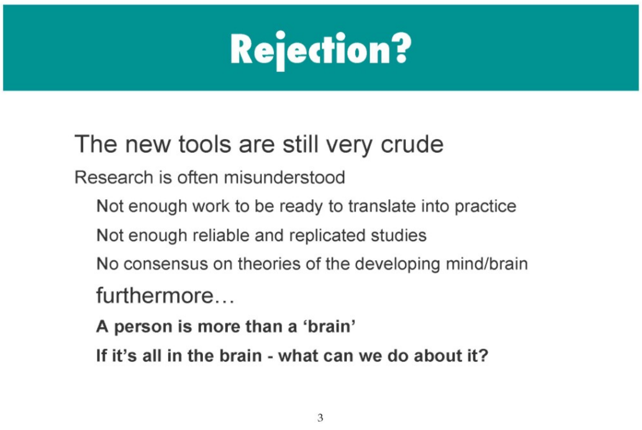
Professor Uta Frith FRS FBA FMedSciEmeritus Professor, Institute of Cognitive Neuroscience, University College London and Visiting Professor at Aarhus University, Denmark.

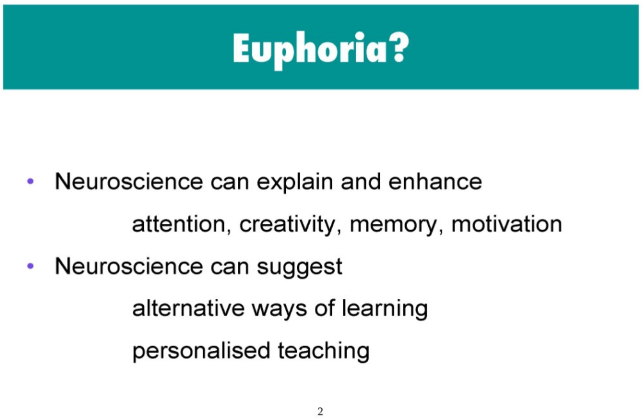
The basic tools that neuroscientists have at their disposal to probe the activation of specific brain regions and to analyse structural changes during development are described here with some preliminary comments about the scope of this work.

It is important to establish clearly what Science can and cannot do at this stage. Educational research and indeed pedagogy has been hampered by attempting to translate early scientific findings into classroom practice too early.

We now have a golden opportunity to work together to enhance the learning opportunities of our students.

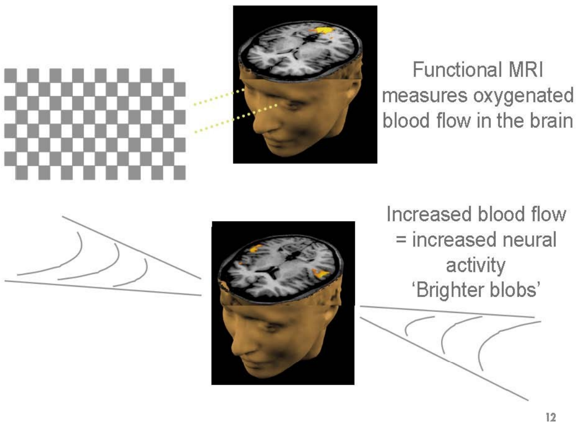
Education is about enhancing learning and neuroscience is about understanding the mental processes involved in learning. This common ground suggests a future in which educations practice can be transformed by science, just as medical practice was transformed by science about a century ago.





Why Now?

We have new and exciting tools to study brain activity and there is much goodwill from scientists and researchers to explore together the areas of mutual interest.

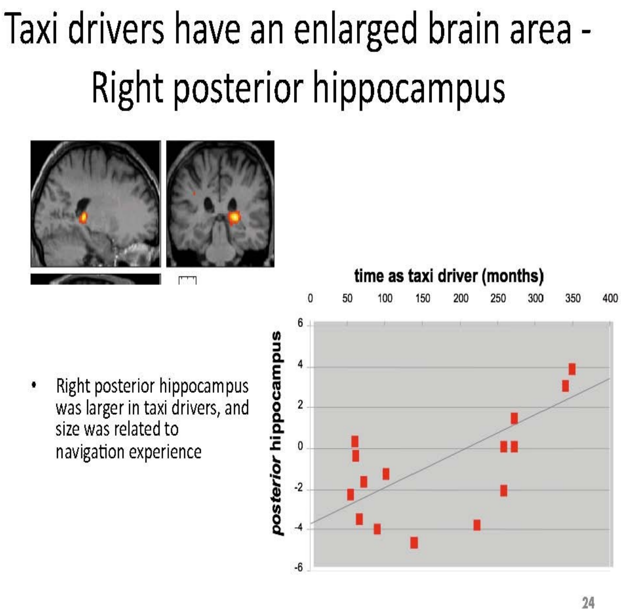


Some preliminary examples.

There are many examples of structural changes occurring in specific areas of the brain as a result of intensive stimulation.

There can be no doubt that the brain is plastic, within limits, and that compensatory learning to offset genetic and or structural limitations works (see Goswami later) occurs.

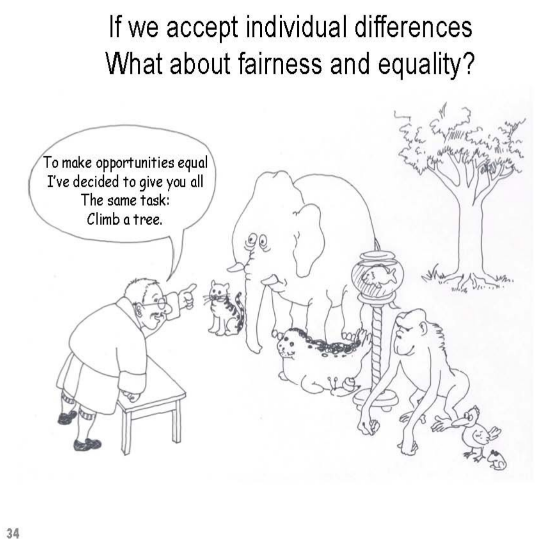
London taxi drivers who have successfully completed 'the knowledge' i.e. learning all of the streets in a 6 mile radius around Charing Cross demonstrate significantly enlarged right posterior hippocampi (see Duzel later) and this increase was related to navigation experience. At least 75% of the candidates drop out and it would be interesting to find correlates of this predisposition (Woollett et al 2009). It is interesting to note that neural development is both increased and reduced. Cell death and neural sculpturing are an important parts of development.



Beware of exaggerated claims

There have been many exaggerated claims that fluid intelligence increases after training in working memory using 'brain training' games. However, following such training, in controlled conditions, only some children showed large gains in working memory and consequently fluid intelligence and clearly this is not a simple relationship. Many factors such as motivation and salience (see Duzel later) play a key role here. Individual differences play a crucial role Jaeggi et al (2008).

Individual differences exist that are due to genetic makeup (as shown in twin studies see Plomin later). However, influence is probabilistic and not deterministic. It is quite clear that pedagogy can overcome many of these limitations but we must understand what these limitations are and how the brain is designed to overcome them most effectively.



Strategies for the future

Your ideas are needed:

- How can neuroscientists and educators best collaborate?
- What would have most impact upon education?
- How can we discern between the good and the bad in advertised teaching programmes purporting to be science based?

We know:

- Education changes the brain.
- It is not enough to say each individual is different. Some of the reasons for the differences can be revealed.
- Education is not a quick fix.

Neither euphoria nor rejection:

Let's have a dialogue

Let's remain sceptical

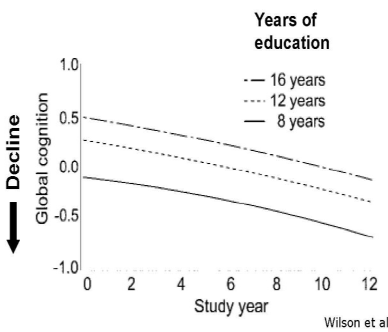
.

Neuroeducation: Making the most of Our Minds.

Barbara Sahakian FMedSci Professor of Clinical Neuropsychology , University of Cambridge.

People with more years of education have better cognition

- **Life long learning and continuing education**



Wilson et al., 2009, Neurology

EXCELLENCE IN SCIENCE

THE ROYAL SOCIETY

What do we mean by a good education?

- Realizing an individual's potential for learning how to learn, for flexibility of thought and for resilience in the face of stress.
- A good education should enhance creativity, innovation and wellbeing for the individual and enhance contribution to society.

What is Neuroeducation?

- Neuroeducation is the use of evidence-based knowledge about the brain in the context of education in order to enhance learning ability

How might Neuroscience help?

- Understanding speech, literacy and numeracy.
- Understanding the important role of motivation and reward.

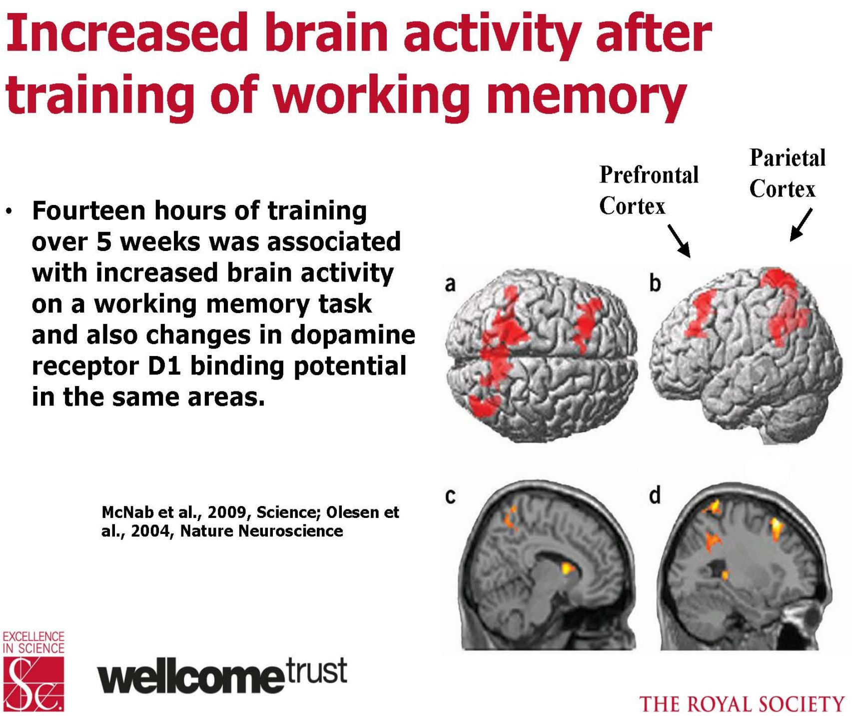
Cognitive Training

Despite the limitations mentioned previously, concerning working memory and fluid intelligence in children, there is good evidence to suggest that cognitive training in adults and continuing education is highly beneficial.

•Engaging in mentally stimulating activities from middle age is correlated with lower incidence of dementia

•Cognitive training has been shown to improve cognitive abilities and slow cognitive decline in older adults

•"...older individuals who report higher levels of well-being also have better cognitive function" (Beddington 2008)



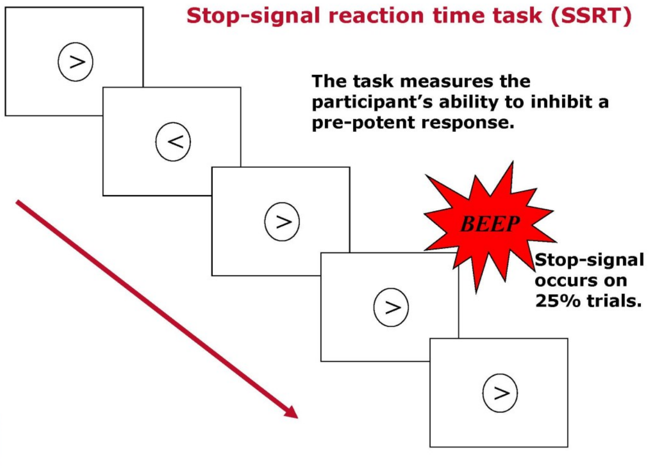
Motivation Dopamine and and Learning

See Duzel later:

All teachers know the importance of making tasks relevant and stimulating. However, the importance of novelty has been underestimated and this suggests that engagement using, for example, computer games may be much more important than we thought. This is not simply a trivialization of the educational process but an important tool to use and enhance performance. The role of the neurotransmitter Dopamine in this process is crucial.

Impulsivity and Cognitive Control

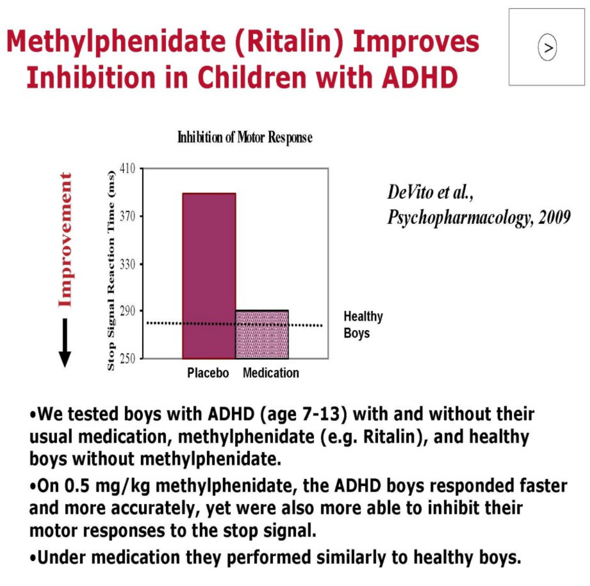
Impulsivity is a feature of the behaviour of children and education and cognitive development are crucially dependent upon its control. This is a feature of the development of the frontal lobes and is not complete until the end of adolescence (the relationship between impulsivity and risk taking will be discussed later, see Burnett).



Four year old children who delayed gratification in certain laboratory situations developed into more cognitive and socially competent adolescents, achieving higher scholastic performances and coping better with frustration and stress. Such tasks usually offer higher reward for the longer delay in gratification Mischel (1989). The ability to inhibit a familiar and programmed patterns of responses can easily be measured in children and adults in a fMRI scanner using the following type of task, where they are presented with a screen containing either a left - or right-pointing arrow. Each subject is told to press a corresponding left or right key, ***unless*** a sound was played after the presentation of the arrow, in which case subjects had to refrain from pressing the button (although this sound was only played on 25% of trials). The delay between the display of the arrow and the onset of the sound was dynamically calibrated to each subject while in the scanner, such that each subject was getting around 50% of the "stop trials" correct and 50% incorrect. The value of this delay is known as the stop signal delay, or SSD. This is then subtracted from the median reaction time on go trials to arrive at the stop signal reaction time.

Cognitive Enhancing Drugs

Work with children exhibiting ADHD has shown the value of using a range of drugs that have the effect of inhibiting impulsive responses.

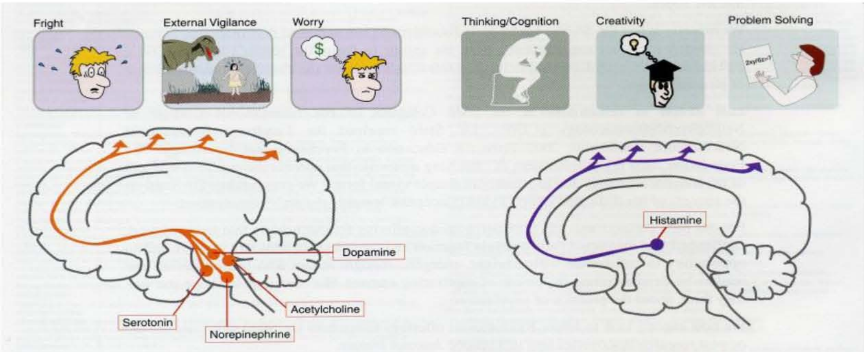


Neuro-enhancing drugs to improve attention, concentration and cognitive control

Methylphenidate (Ritalin) increases synaptic concentration of Dopamine and Noradrenaline by blocking their reuptake.

Atomoxetine (Strattera) is a relatively selective noradrenaline reuptake inhibitor (SNRI).

Modafinil (Provigil) action is unclear; Possibilities include: indirect mediation of ACh and/or Adrenergic alpha –1 receptor activity. Appears to effect hypothalamic orexin and histamine, and has a small effect on dopamine transporter activity. Recent evidence suggests NA (Minzenberg et al 2008) or DA mechanisms (Volkow et al 2009).



Stahl, 2002, J Clin Psychiatry

EXCELLENCE IN SCIENCE

wellcome trust

THE ROYAL SOCIETY

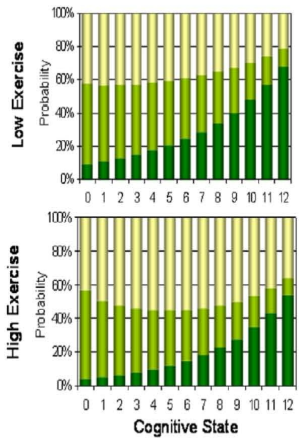
Exercise and Cognition

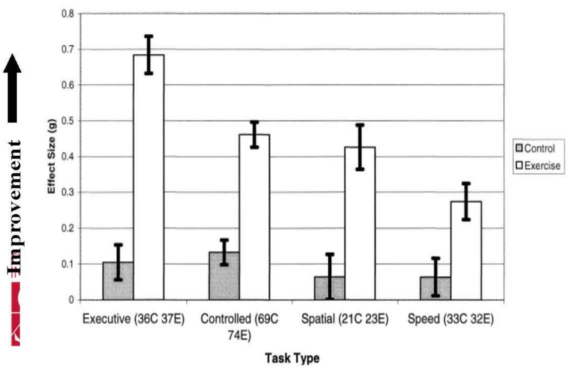
Cognition improves on a range of measurements following exercise. As we have probably always known there is now good evidence for this phenomenon throughout life. Furthermore animal research indicates increased neurogenesis following exercise.

Further study will indicate more precise relationships between type of activity and subsequent benefits

Exercise and Cognition in Older Adults

- **Exercise is strongly associated with improving cognition** (Middleton et al., 2008)





- **Fitness training enhances cognition in healthy older adults** (Colcombe & Kramer, 2003)

THE ROYAL SOCIETY

Future Directions

Progress will depend upon the interrelationship between a number of disparate disciplines.

The following should be considered:

•Build networks to facilitate the exchange of ideas.

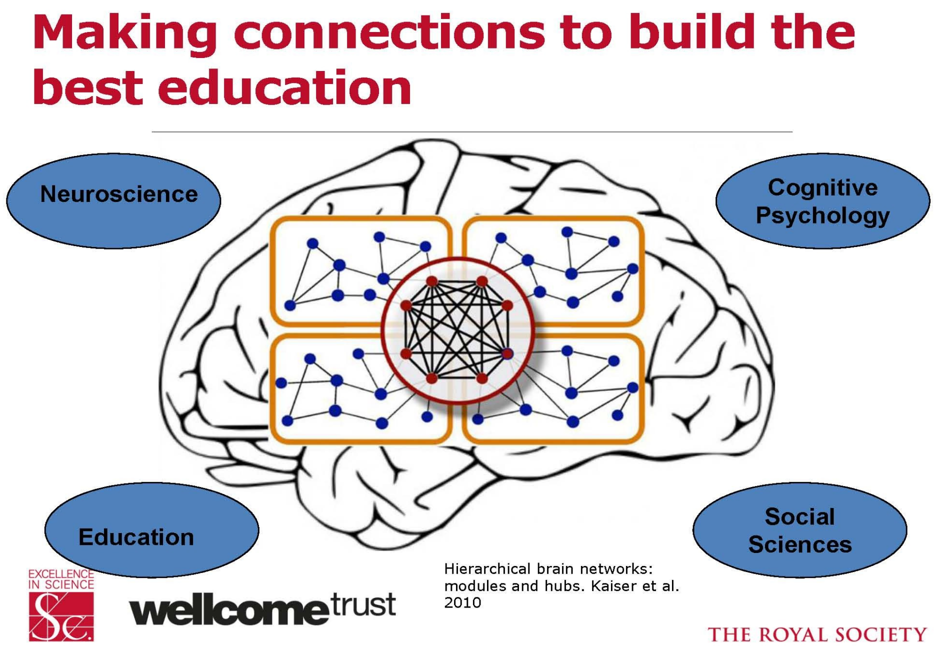
•Bridge research and practice to translate novel findings into evidence-based learning.

•Knowledge of neuroscience relevant for education should be part of continued professional development (CPD) for teachers, especially those involved in special educational needs

•Realise benefits and opportunities for well-being, health, employment and economy. For example, neuroscience can make valuable contributions to the development of adaptive technologies for learning (e.g. cognitive training could be promoted via the UK games industry)

•New educational technologies provide opportunities for personalised learning that our education system cannot otherwise afford

•Contributions to neuroeducation will come from many disciplines and we need to work together to make the most of our minds.

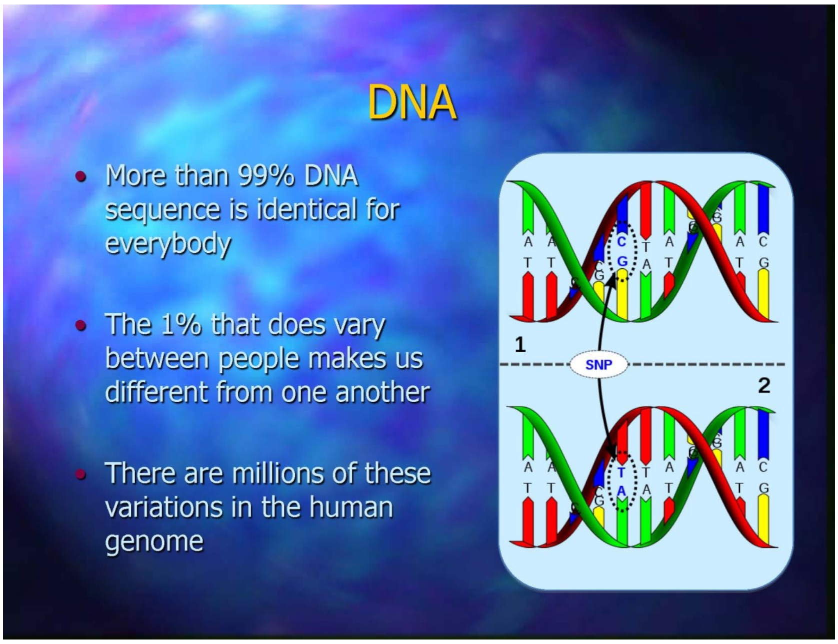


Genetics of cognitive abilities and disabilities

Professor Robert Plomin: Professor of Behavioural Genetics at the MRC Social, Genetic and Developmental Psychiatry (SGDP) Centre at the Institute of Psychiatry, King's College London.

The last century has been one that, scientifically, has been dominated by an exponential rise in our level of understanding about our genetic basis. However, despite this rise in molecular understanding there has still been a disconnect between the search for qualitative traits, that show simple patterns of inheritance, and biometricians who focused on quantitative traits that are normally distributed. These two worlds are now being brought together by 'genome-wide association research' (GWA) which shows that the ubiquitous heritability of common disorders is due to multiple genes of small effect size.

The finding that multiple DNA variants are associated with common disorders is leading to disorders being thought of in quantitative terms.

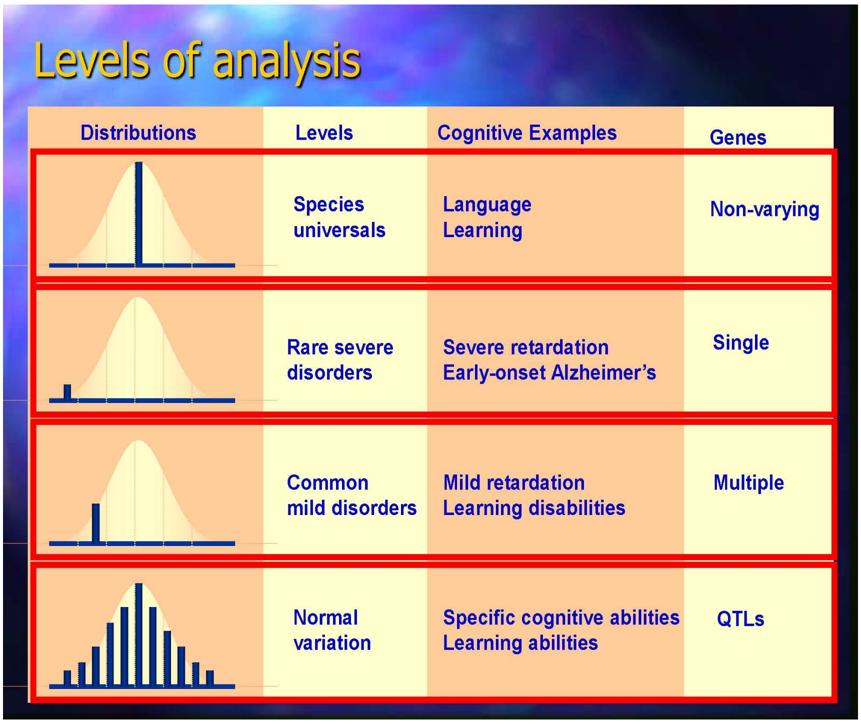


Quantitative Trait Locus (QTL) model.

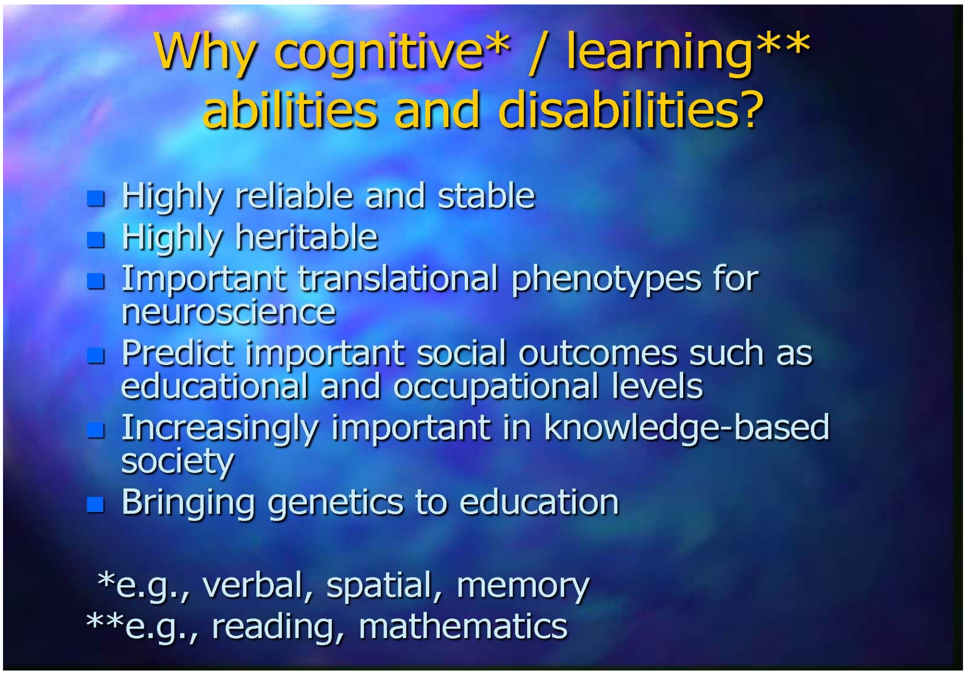
A general consensus in genetics exists today—that all variation in all complex traits, including all psychological and behavioural traits, is partly explained by DNA differences (polymorphisms) among people, that many DNA polymorphisms are involved in each trait and that each polymorphism explains very little of the variation in any given trait.

Learning disabilities such as dyslexia, dyscalculia, and ADHD have been conceptualized as quantitative cut-offs on one or several dimensions at the extreme end.

The QTL model implies that each individual is likely to have their own unique combination of genetic variants contributing to their abilities and performance.


Levels of analysis

Distributions	Levels	Cognitive Examples	Genes
	Species universals	Language Learning	Non-varying
	Rare severe disorders	Severe retardation Early-onset Alzheimer's	Single
	Common mild disorders	Mild retardation Learning disabilities	Multiple
	Normal variation	Specific cognitive abilities Learning abilities	QTLs

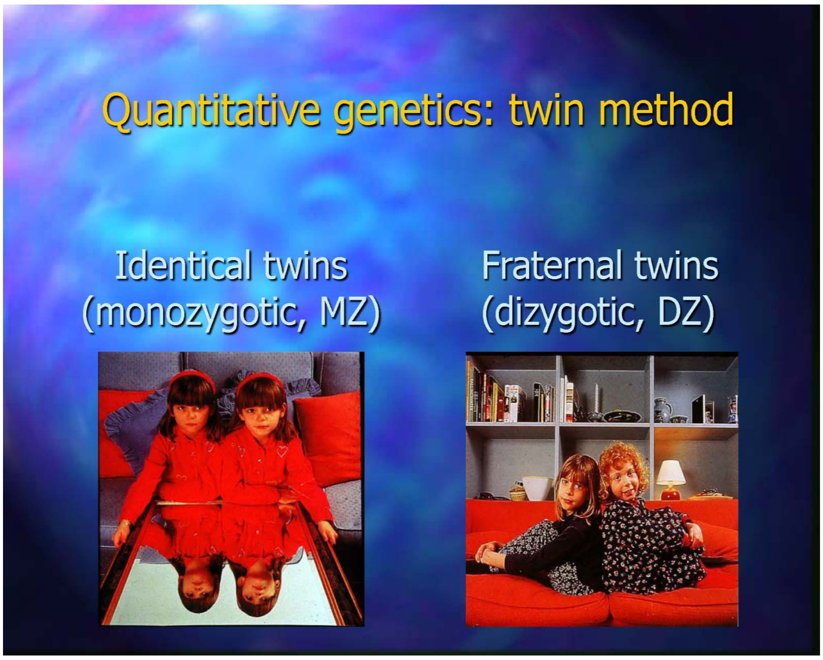


Quantitative genetics: Twin Studies

Simple calculations of the heritability of a trait can be made using twin studies with, preferably, large numbers of identical and fraternal twins in the same study.

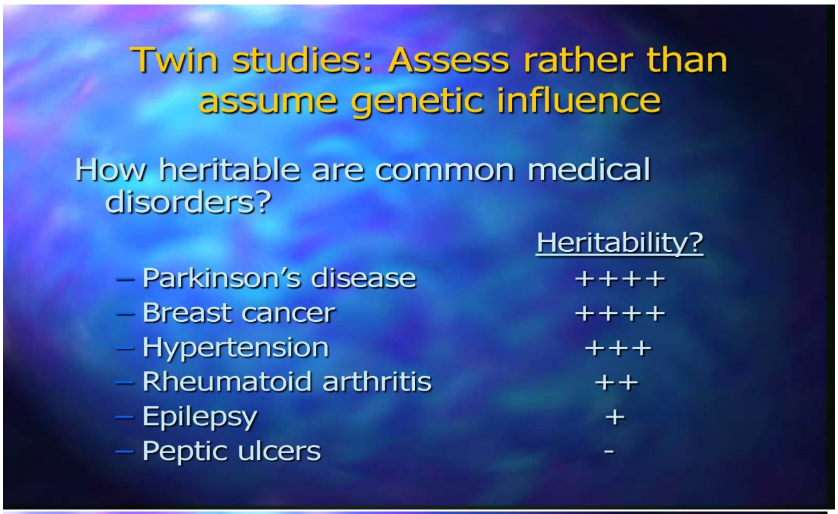
If identical and fraternal twin correlations are the same, heritability is estimated as zero. If identical twins correlate 1.0 and fraternal twins correlate .50, a heritability of 100 percent is implied. In other words, genetic differences among individuals completely account for their phenotypic differences. A rough estimate of heritability in a twin study can be made by doubling the difference between the identical and fraternal twin correlations. IQ correlations for identical and fraternal twins are .85 and .60, respectively.

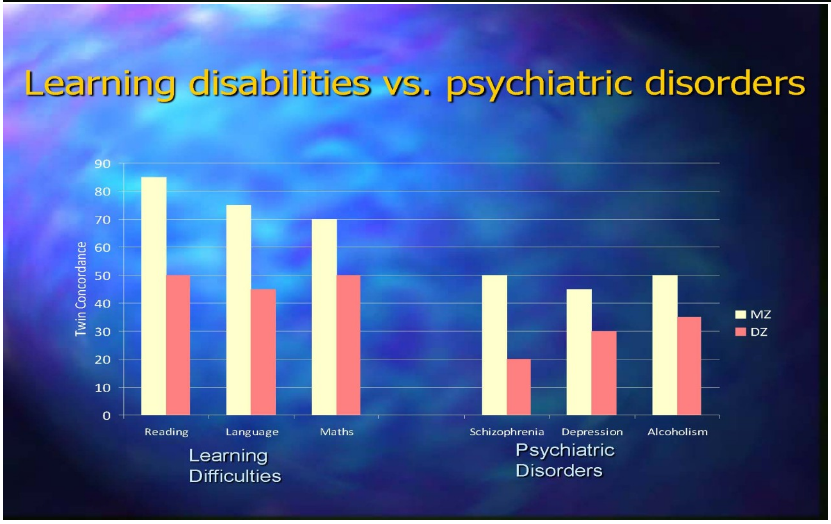
Doubling the difference between these correlations results in a heritability estimate of 50 percent, which also suggests that about half of the variance of IQ scores can be accounted for by genetic factors. Because these studies include more than 10,000 pairs of twins, the error of estimation is small. There is a 95 percent chance that the true heritability is between .48 and .52.



How heritable are common traits?

For learning disabilities MZ and DZ twin concordances are about 85% and 50% respectively and are similarly different for reading and for language and mathematics. These results indicate substantial genetic influence on learning difficulties which is greater than for most other common psychiatric disorders.

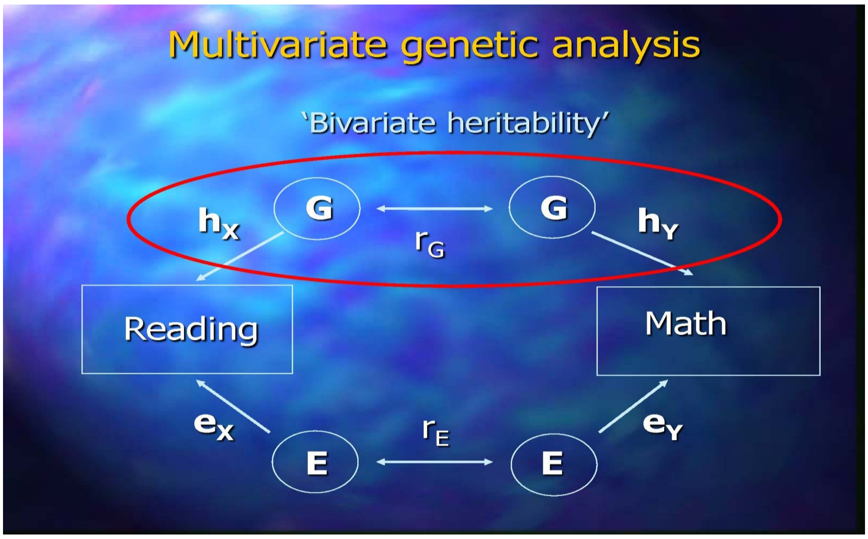




Do different genes affect different cognitive abilities?

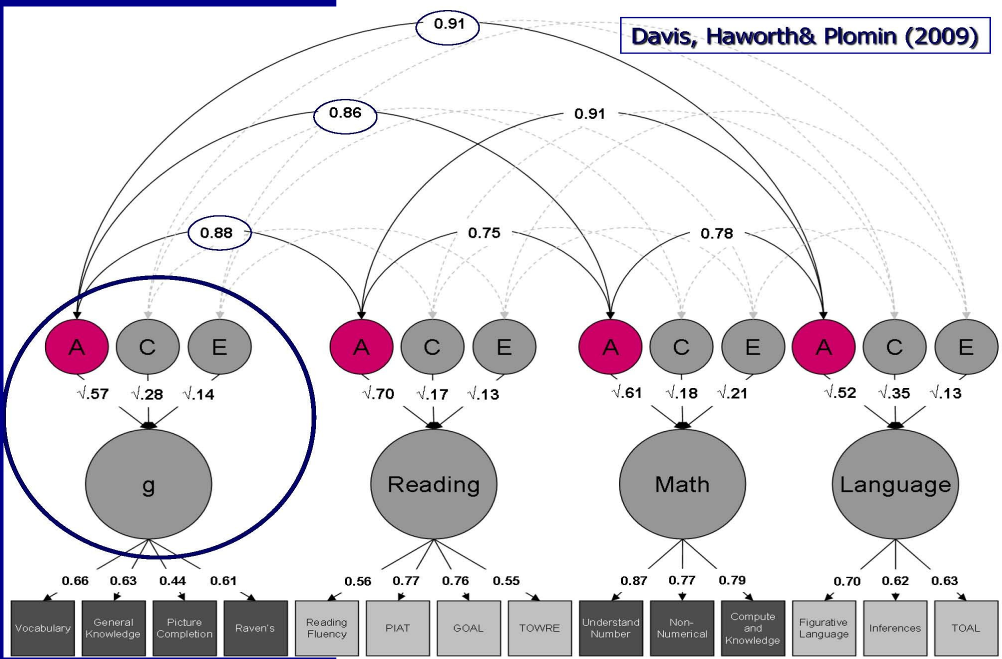
Quantitative genetic research has shown that the same genes affect different learning abilities and disabilities (see later).

These surprising findings derive from multivariate genetic analysis , which investigates not only the variance of traits considered one at a time but also the covariance among traits. Multivariate genetic analysis estimates the extent to which genetic and environmental factors affect one trait and also affect another trait. It reveals a statistic called the 'genetic correlation 'which indexes the correlation between genetic effects on the two traits independent of the heritabilities of the two traits. Importantly then the genetic correlation between two traits can be 1.0 even when the heritabilities of the two traits are modest. This has led to the ***Generalist Genes Hypothesis.***



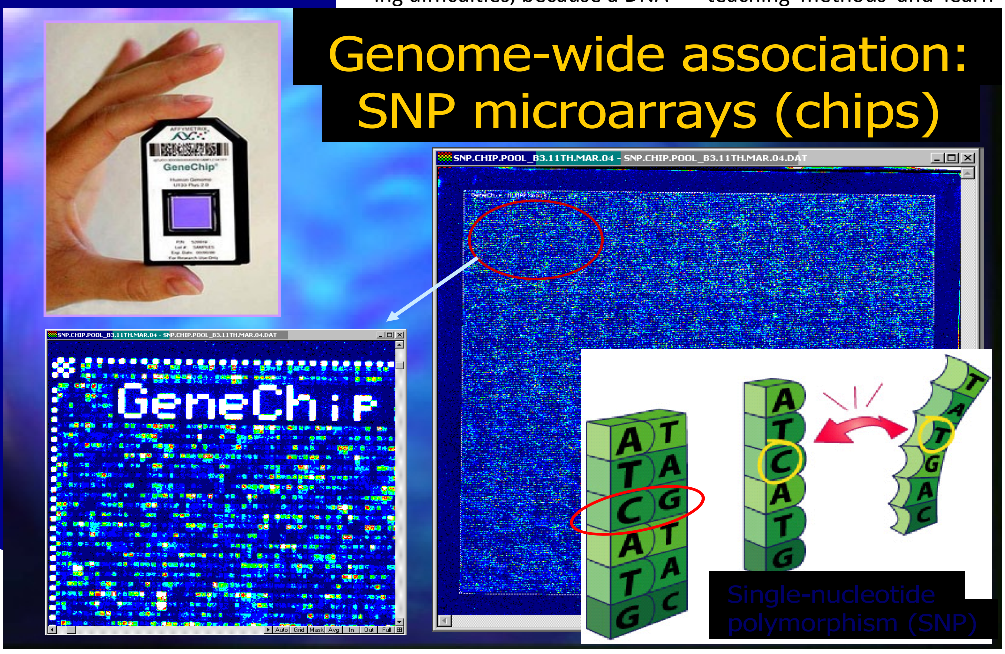
Generalist Genes

In a review of a dozen multivariate genetic studies of learning abilities and difficulties (it is important that quantitative genetics is looking at a normal range of ability) the average genetic correlation was 0.7 between reading and language, reading and mathematics, and language and mathematics. Similar results emerge both in middle childhood and early adolescence. This has very important implications in that it appears that the same set of genes is largely associated with most learning problems and it should therefore be much easier to find what these genes are and do.



Molecular Mechanisms

Identifying the genes responsible for the genetic effects on variation in learning will provide the ultimate early diagnostic indicators of learning difficulties, because a DNA sequence does not change as the result of development, behaviour or experience. Finding these genes may facilitate the most suitable teaching methods and learning environments for individual cognitive and motivational profiles. However, progress towards finding these genes is slow because the genetic predisposition involves a very great number of genes of small individual but large cumulative effect. Nevertheless such genome-wide association is made possible by DNA microarrays (often called gene-chips) that can genotype as many as a million DNA markers inexpensively. Soon it will be routinely possible to analyse the entire genome.



Molecular genetic investigation into mathematical ability.

Only one molecular genetic investigation into mathematical ability has been reported so far. In this first large genome wide-associated study, 10 single nucleotide polymorphisms (SNP's) were nominated as associated with mathematical variation in 10-year old children who were participating in the Twins Early Development study. Consistent with the results from twin studies, which suggest genes work additively, when these SNP's were combined into a set they accounted for 2.9% of the phenotypic (observed) variance in mathematics. One of the SNP's is in a NRCAM gene which encodes a neuronal cell adhesion molecule, potentially opening a window into one of the general brain mechanisms.

GWA results for maths:
'Top 10' individual genotyping results

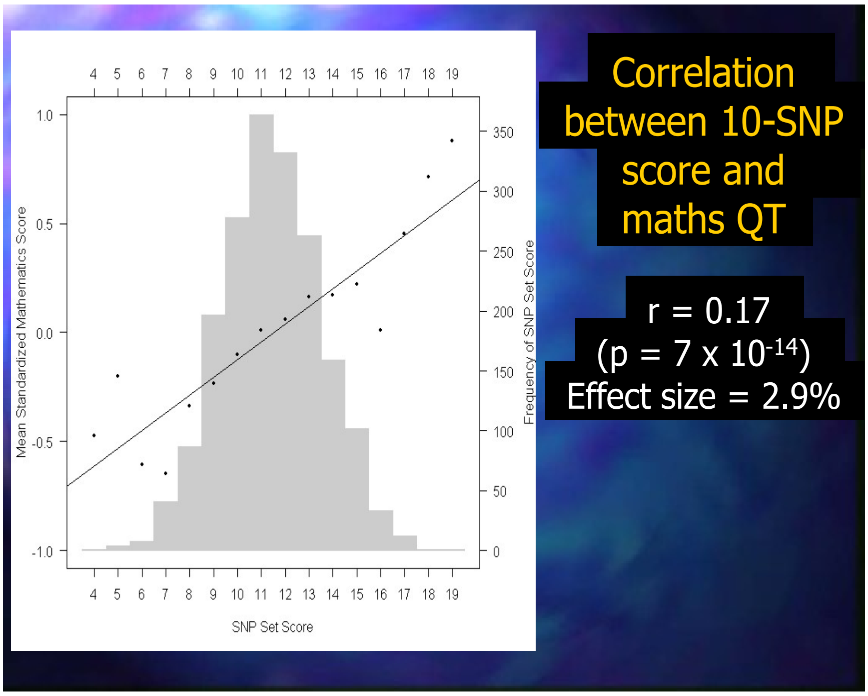
SNP rsID	Chr	Position	A	B	MAF	N	Mean AA	Mean AB	Mean BB	P	% Variance	Nearest Gene
rs11225308	11	101904688	G	T	0.23	2179	-0.289	-0.037	0.047	**0.0002**	0.58	MMP7
rs363449	21	29906146	C	G	0.38	2177	-0.072	0.012	0.141	**0.0006**	0.49	GRIK1
rs17278234	5	13990476	C	T	0.31	2183	-0.157	-0.031	0.062	**0.0008**	0.46	DNAH5
rs11154532	6	130567068	C	T	0.23	2173	-0.096	-0.062	0.047	**0.0054**	0.30	SAMD3
rs12199332	6	157185419	A	G	0.20	2111	-0.015	-0.093	0.044	**0.0086**	0.27	ARID1B
rs12613365	2	191055555	G	T	0.25	2179	-0.038	0.036	0.090	**0.0246**	0.18	FLJ20160
rs6588923	11	106125102	A	G	0.12	2111	-0.253	-0.051	0.020	**0.0260**	0.18	GUCY1A2
rs2300052	7	107875730	A	G	0.30	2109	0.103	0.015	-0.032	**0.0407**	0.14	NRCAM
rs6947045	7	107287183	C	T	0.43	2179	-0.070	0.041	0.014	**0.0451**	0.13	DLD
rs1215603	12	105041007	C	T	0.44	2179	-0.046	0.008	0.055	**0.0463**	0.13	NUAK1

Docherty et al (2010) *Genes, Brain & Behavior*

Quantitative techniques to further understand the role of these genes in Mathematical learning.

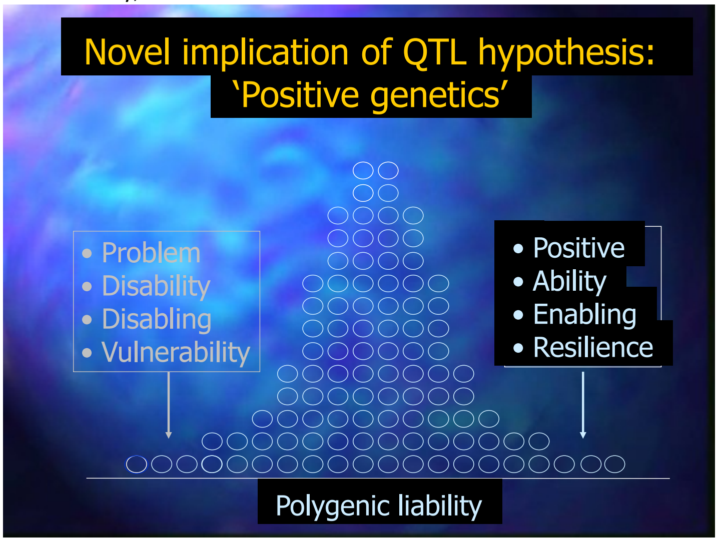
By using the 10 SNPs described above and the Twins Early Development Study's longitudinal multivariate dataset it was found that many of the same genes influence diverse cognitive abilities and disabilities across age. 4927 children were genotyped on these SNP's and had data available on measures of mathematical ability as well as other cognitive and learning abilities a 7, 9, 10 and 12 years of age. Using these data the assessments were made of the association of the available measures of ability at age 10 and other ages with the composite SNP-set scores. The SNP-set score is calculated by adding up a score for each of the SNPs. For each SNP, an individual can have a score of 0 (no maths increasing variant allele), 1 (one maths increasing allele). Note each gene has two alleles and each individual may have 0, 1 or two. Because there are 10 SNPs, SNP-set scores can range from 0(no maths increasing alleles) to 20 (both alleles at all 10 loci are maths increasing.

It should be noted that the SNP set associated with overall mathematics score was also associated with the three mathematical components, computation, non-numerical knowledge and understanding number.



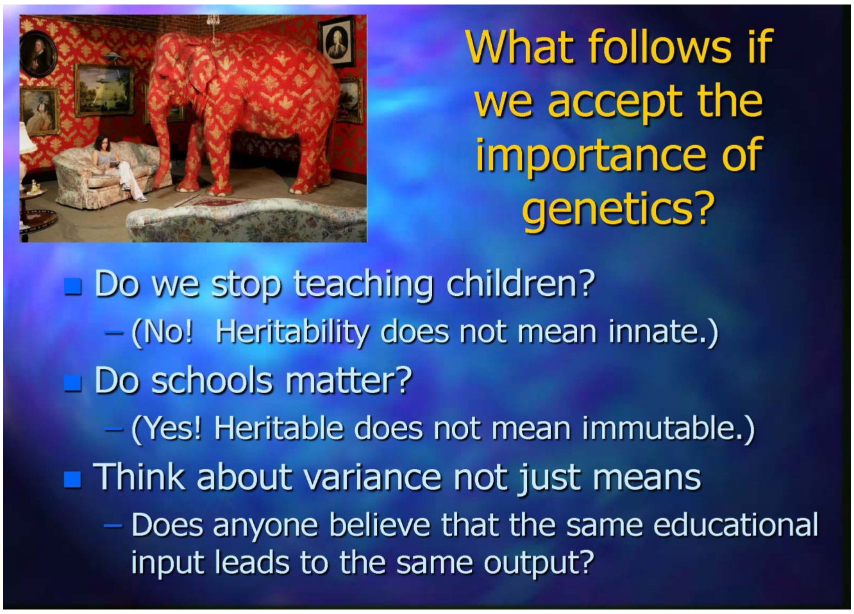
Positive Genetics

The great strength of quantitative genetic methods is that they investigate the net effects of genetic and environmental influences simultaneously, which means that quantitative genetic studies are as much studies of the environment controlling for genetic effects as they are genetic studies controlling for environmental effects. Therefore instead of the child being a passive recipient of environmental events, the GE correlation model supports an active view of experience in which children make their own environments in part on the basis of their own genetic proclivities.



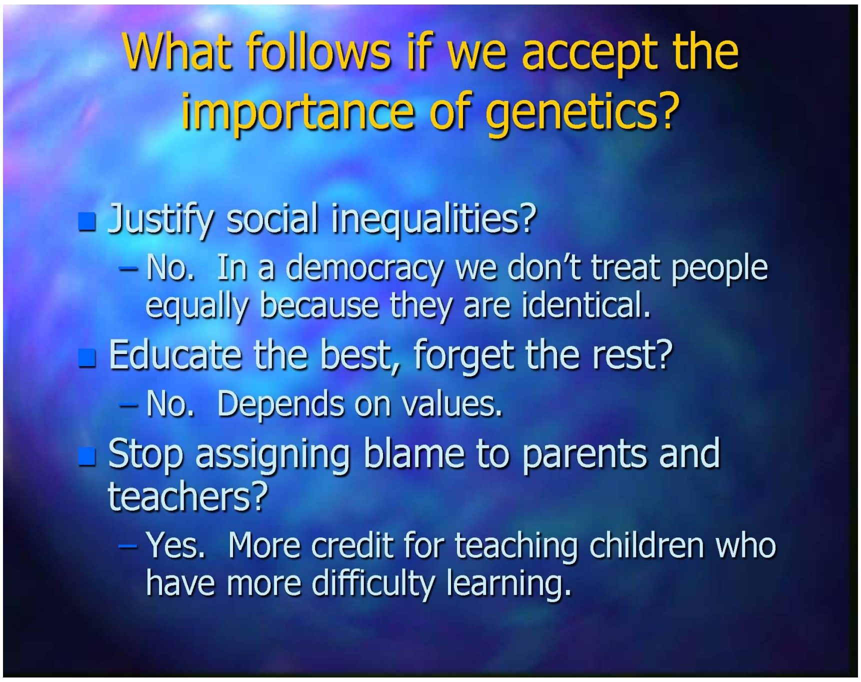
General implications of genetics for education.

Children select, modify, construct and even reconstruct experiences for genetic reasons, creating correlations between their genotypes and their environments. Where do parents and policy makers fit in this GE correlation model?



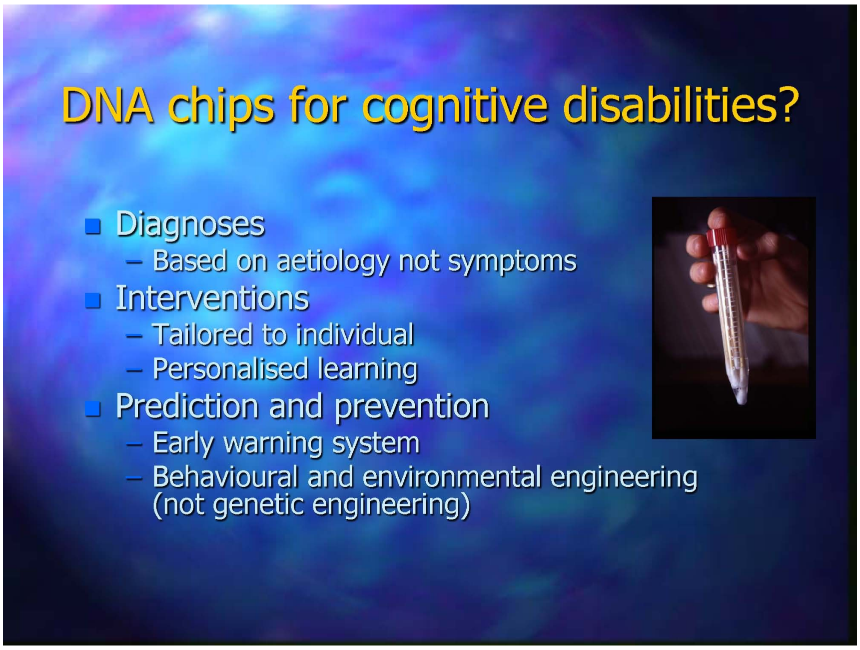
The implications of Genetics

Genetics in education is often mistakenly associated with inequality. Moreover, much of the educational research on mathematics and other subjects is devoted to finding the best methods for teaching mathematics in a one size fits all approach. This seems paradoxical because teachers, more than anyone, know that each child has a unique cognitive profile and even students who perform adequately may learn in diverse ways. The existence of large individual differences in learning (as determined by quantitative genetics) means that determining the appropriate pedagogical approaches for each maths skill, for example, will not be enough to optimize education for each learner. Future education using the power of computers to personalize learning, as well as differentiated teaching methods and learning paths may achieve previously unimaginably optimized outcomes.



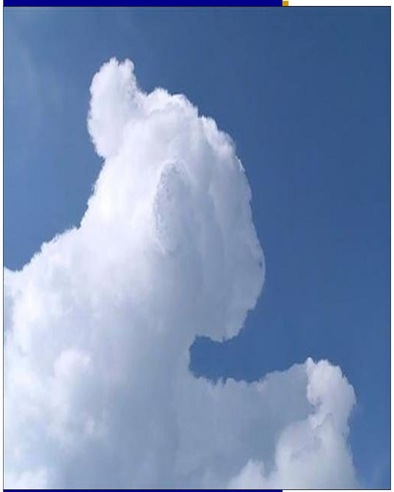
The future

In the future it is possible that an individual's DNA sequence could be examined for educationally-relevant variation in order to suggest the best methods, compensatory strategies and learning approaches for each individual. A useful future direction is understanding the processes through which resilience operates—understanding the sources of high maths performance, despite poor performance on early predictor abilities.



The Contribution of Evolutionary Biology to theories of learning.

Professor Michael Reiss: *Professor of Science Education , Institute of Education, University of London*



Humans are the product of some 3,500 million years of biological evolution. Those of us who are alive today are an indescribably small proportion of those who could be alive had natural selection not weeded most of them out. The importance of these facts has rarely been considered for education. Our evolutionary heritage is of profound importance for how we learn, including what we find easy to learn and what we find difficult.

Our perceptual apparatus is highly constrained for example by having a tendency to see animate shapes in non-material objects, we are much more aware of movement than non-movement and over-interpret in an evolutionary logical way e.g. we interpret bumps in the night as possible intruders!

Many for example (Humphrey 1976) have argued that such constraints stem from our evolution as social animals. The driving force behind our cognition is the competitive pressures of being social and simply keeping our wits about us. There are many examples of fallacious reasoning which would fit such an interpretation. The most obvious are those when men openly resort to animistic thinking about natural phenomena. Thus primitive and not so primitive peoples often commonly attempt to bargain with nature. In so doing they are adopting a social model, expecting nature to participate in a transaction. These predispositions are deeply rooted for good evolutionary reasons but do on many occasions result in illogical behaviour.

The arrival of Man Friday on the scene was the thing that really made things difficult for Crusoe. If Monday, Tuesday, Wednesday and Thursday had turned up as well then Crusoe would have had every need to keep his wits about him.

Phenomenological Primitives

We act in accordance with certain evolutionary-based intuitive assumptions as Andy DiSessa (1983) has termed them "p prims" phenomenological primitives.

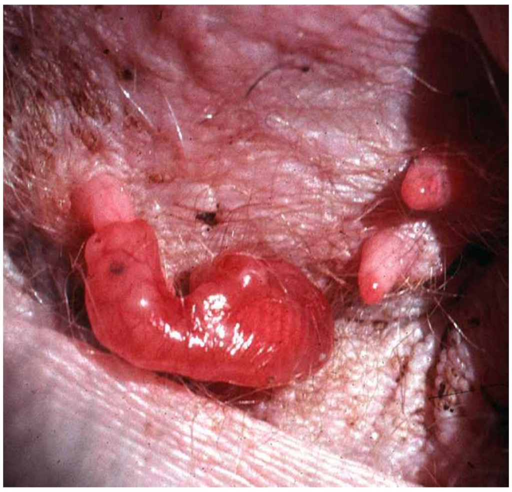
This can have a major impact upon the way we interpret natural phenomena. For example we may believe in the spontaneous resistance that seems to be inherent in an object rather than the impact of an external force such as resistance that Newtonian physics tells us is the real explanation. In a similar vein Reiss and Abrahams (2010) suggest the this may be reduced to even more basic assumptions (ur-prims) such as changes to inanimate objects are generally the result of causes whereas animals are agents who can move on their own (so it is not surprising when a dog moves without anything coming into contact with it but it is when a meaningless shape does).

If an effect has a number of potential causes, the actual cause is likely to be one that covaries with the effect (so by the time they are three years old, children can work out which of a pair of levers on a box causes the light on the lid of the box to come on).

Control of Reasoning

Offspring have characteristics that resemble those of their parents (so when four-year-olds are shown a picture of a newborn kangaroo – a shapeless blob – and then told that it was raised with goats they are almost all sure that it grows up to be good at hopping not climbing).

Psychologists have come to the conclusion that there are at least two different systems operating when it comes to thinking and reasoning. One system is believed to be evolutionarily more ancient in terms of human development; it has been called intuitive, natural, automatic, heuristic, and implicit. It's the system that we think is operating in young children before they reach school age. The second system is one that is believed to be more recent in human evolution; it permits logical reasoning but is limited by executive functions.



Resistance to Change

One's preconceptions and belief structures can be very deep-seated and can function very well culturally even though they may be wrong. In other words they work! The work of Kuhn demonstrates how difficult it is to shift paradigms and the conditions necessary for such shifts.

Nevertheless the paradoxes prevalent in science are never far from the surface. Transactional thinking may indeed be irrepressible and all explanatory knowledge of a certain type has a particular place in a priority hierarchy.

Newton is revealed in his private papers as a Rosicrucian mystic and his intellectual decedents continue to apply a strange double standard. For example in particle physics as Humphrey points out we a have world peopled by 'families' of elementary particles endowed with ' strangeness and 'charm'.

The particles searched for at SPEAR were the cousins of the psis made from one charm quark and one uncharmed antiquark. (New Scientist).

The ideology of classical science has had a huge but in many ways narrowing influence upon the nature of intelligent behaviour. But regardless of what science has said about the ways people ought to think it is only now that we are coming close to describing how they do think.

Pedagogical Implications

Science education should both allow pupils to live in the world of pre-science and enable them to live in the world of science, rather as English curricula increasingly accept non-standard English but expect pupils also to know how and when to use standard English and also expect pupils to understand different genres of writing. We should:

- Accept how difficult it is to change minds to think scientifically.
- A mental hygiene approach of purging wrong thinking will not work we need to be able to accept the existence of parallel views of the world.
- We should accept and adapt our teaching to fit with increasing "control of reasoning" (See Goswami)
- It is not until late adolescence (see later Burnett) that executive control and development of the frontal lobes allows this to function fully.
- Teachers then should pay attention to a student's collection of p-prims and seek to modify the priorities those p-prims and not eradicate them.
- When teaching to change mind sets, consider the use of "what ifs" and "imagine ifs" to help set context and provide rationale. Contextualising is also very helpful e.g. teaching the history and philosophy of physics helps in the understanding of the subject.

The Implications of Neuroscience for our understanding of Language and Reading

Usha Goswami: Professor of Cognitive Developmental Neuroscience, University of Cambridge

Children are usually fluent comprehenders and producers of spoken language by the age of 5 years but reading requires further development of phonological representations and this directly influences neural development.

Behavioural studies have shown that **Categorical perception** is crucial in the early development of language. Infants track the distributional properties of the sounds in the language that they hear and register the acoustic features that regularly co-occur. These relative distributional frequencies then yield phonetic categories. Once a prototype is formed nonprototypical members of a category are perceived as more similar to the category prototype than they are to each other this is called the **Magnetic effect.**

General auditory perceptual abilities seem to influence where the physical boundaries for phonetic contrasts are placed by human languages, and general physiological properties of the mouth and jaw seem to influence which sounds are easiest to make and hence which sounds are frequent across languages.

Rhythmic and **prosodic** patterning are also important.

Social Interaction is also crucial in perceptual learning. Infants learn language because they are motivated to interact with partners and to communicate. They do not learn language simply because they are passively exposed to sounds.

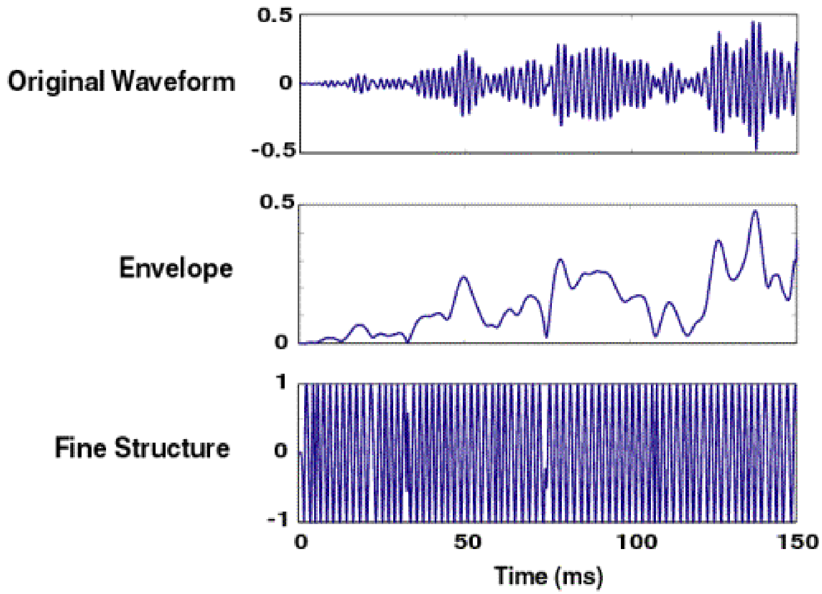
Babies use speech rhythm as an early segmentation cue and they can distinguish between ba and pa sounds for example. There is a measurable point at which sounds that are highly similar physically stop being perceived as /b/ and begin being perceived as /p/. This is called **categorical perception.**

Infants were exposed to repeated background sound of, for example, the syllable ba. The rate of sucking on the experimental dummy declined. This increased again when pa became detectable by changing the voice onset time.

Amplitude envelope perception, phonology and prosodic sensitivity.

Any sound can be mathematically factored into the product of a slowly varying **envelope** (also called modulation) and a rapidly varying fine time structure (also known as a carrier). The envelope is the loudness contour of the sound signal. The fine structure contains the subtle details of a sound signal and enhances pitch and sound quality.

Recent studies have shown that perceptual insensitivity to amplitude modulation can explain the difficulties with some phonetic contrasts experienced by children with developmental dyslexia.



Cognitive neuroimaging of phonological development

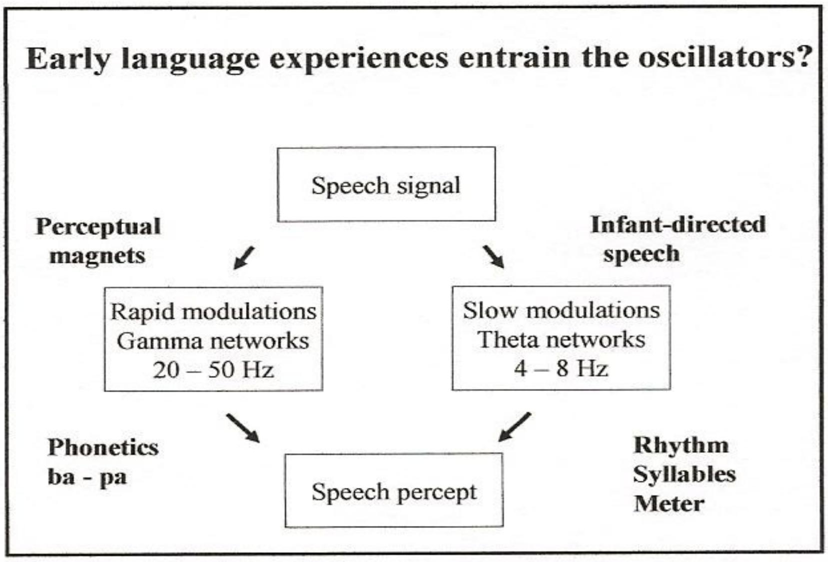
Using EEG methodology it can be shown that when a stimulus such as /p/ is repeated many times there is a decreased activity in the network of neurons that respond to auditory /p/ signals (i.e. habituation) However, if the stimulus is changed back to /b/ there is renewed activity. This measurement is known as the mismatch negativity or **MMN.**

Studies using fMRI and EEG are beginning to reveal corroboration of earlier findings from more conventional measurements.

It has been argued from these studies that the infant cortex is already structured into several regions of functional importance for speech processing by the age of 3 months.

What and Where pathways

Studies using fMRI with adults have shown that, as in the visual system, there are two pathways for processing incoming signals in the auditory system. An anterior pathway is interested in information about vocalizations and acoustic phonetic cues (what are they). The second, posterior, pathway is more interested in information about sound localization and how sounds are made hence articulatory information. EEG data indicates resolution into rapid modulation gamma networks (20-50 Hz) and slow modulation theta networks (4-8 Hz). It is argued that the anterior acoustic phonetic pathway may be entrained using perceptual magnets and the posterior articulatory pathway by infant directed speech.



Sound categories and reading

Symbolic systems enable human cognition to develop beyond biological constraints. However, the acquisition of symbols requires social transmission (e.g. by teachers) but is also, of course, highly dependent upon the cognitive prerequisites of the child.

The implications of the above for language development before school are that children can be and should be exposed to stimuli that allow categorical, rhythmic and prosodic patterning to develop.

Therefore they need to:

- Hear as much language as possible.
- Rich language is important.
- Story reading interactions.
- Mechanisms to entrain the oscillators such as nursery rhymes, poetry, music and singing.

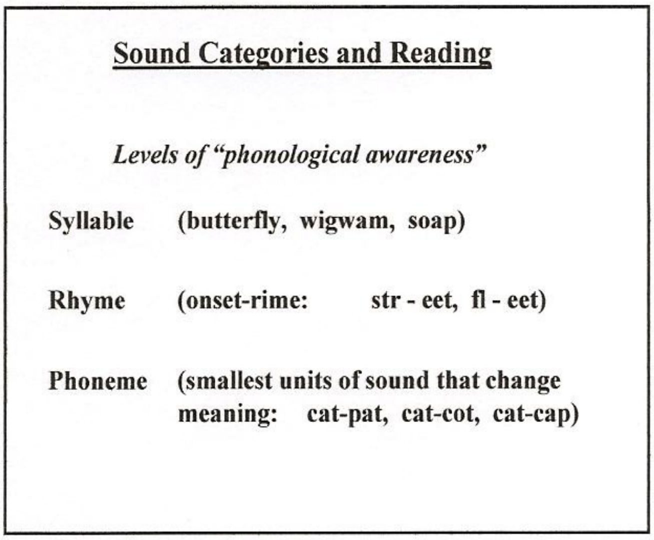
Reading develops upon this sound fundamental basis. It is not innate but phonological activation appears mandatory during reading and builds upon patterns already developed but it needs careful entraining depending upon the language being read.

Phonological Awareness

We have seen that prosodic cues that are exaggerated in infant-directed speech namely changes in pitch, duration and stress carried important information about word boundaries and about how sounds are ordered into words.

In reading children first gain awareness of syllables, then onset-rhyme units, and finally phonemes.

Phonological awareness is also called metalinguistic awareness highlighting the fact that the child needs to become consciously aware of knowledge that is already present in the mental lexicon. However, the rate at which this correspondence develops is dependent upon the transparency of the orthography. In many languages this structure is simple; syllables are CV (consonant vowel) structures and onset rhymes and phonemes are equivalent (for example Italian). Whereas in English this may be complex. That is to say the onset may be complex. For example in the words sing, sting and spring all share the same rhyme ing. However the onset is /s/, /st/ or /str/.



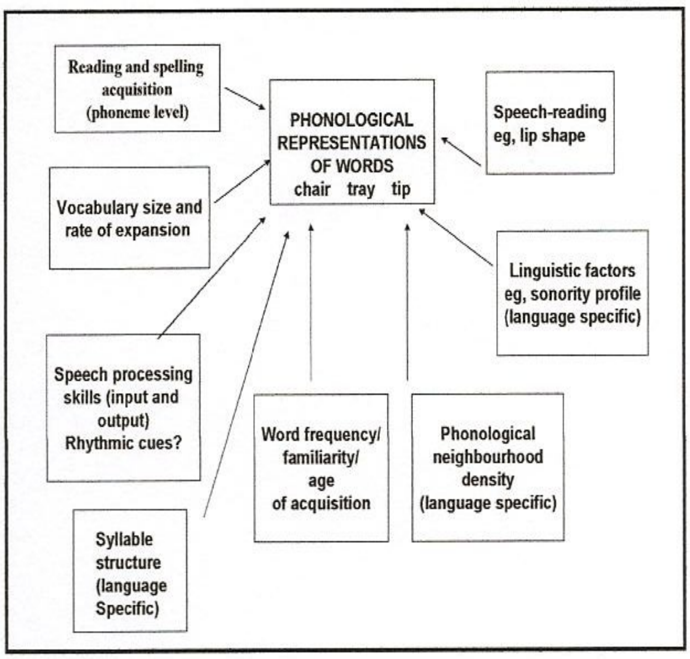
Training phonological skills the impact of

The existence of a robust longitudinal association between phonological awareness and subsequent literacy does not in itself show a causal relationship.

Similarly if interventions are made to test the impact of phonological training appropriate controls must account for the possible Hawthorn effect (i.e. impact on attention, motivation etc. resulting from enthusiastic intervention and co-action effects).

For example children might be taught to put pictures of a hat, rat and bat together when grouping by rhyme. A control group spent the same amount of time with the same researchers and same games but learnt to group words by semantic category.

This particular intervention revealed significant differences in reading and spelling subsequently.



Educational Neuroscience

One attractive feature of neuroimaging is that it can reveal changes in neural organization following such interventions. For example, if an intervention is targeted at improving phonological skills then neuroimaging can show whether neural activity is actually in the structures which support phonology. If we were for example looking at other factors (Hawthorn effect) we would not expect to see this.

Across spoken languages, the neural networks that develop for language are left-lateralized in the frontal and temporal regions of the brain. Reading also seems to be left-lateralized.

Intervention studies show that neural activity in the left lateralized sites increases following intervention.

Educational Neuroscience

Importance of understanding how the brain encodes information

Importance of understanding how environment shapes the basic encoding

Focus on causal mechanisms of development

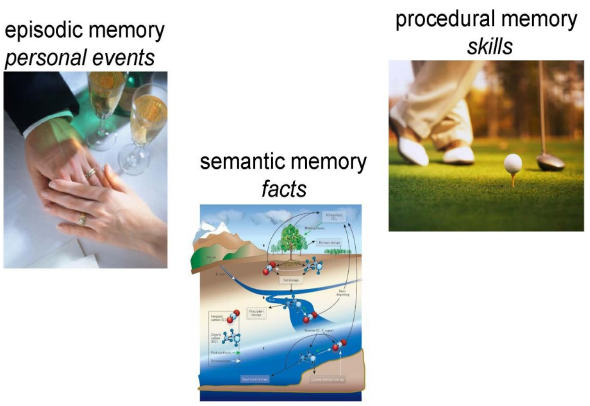
Deeper understanding of brain-environment interactions re: pedagogy and remediation

The Lure of the Unknown: Motivational aspects of memory

Emrah Duzel Professor of Cognitive Neuroscience, University College London, Honorary Consultant Neurologist National Hospital for Neurology and Neurosurgery

Psychologists have studied learning and memory extensively and they have distinguished a number of functionally different types of memory.

The different kinds of memory

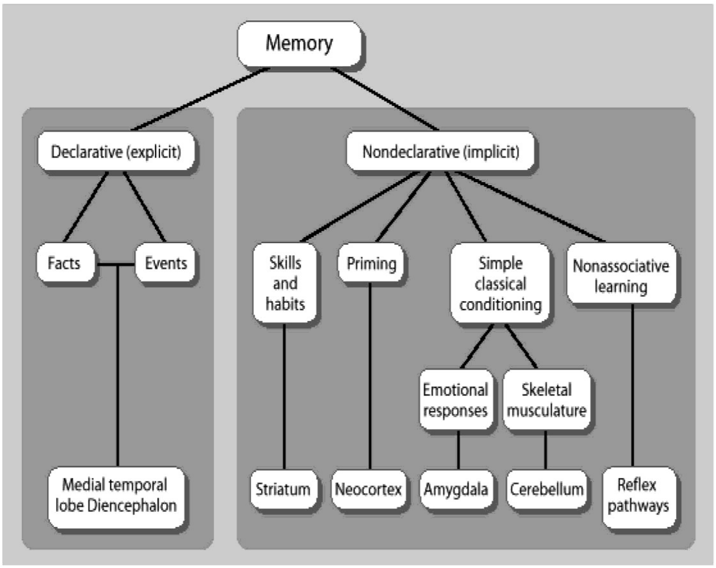


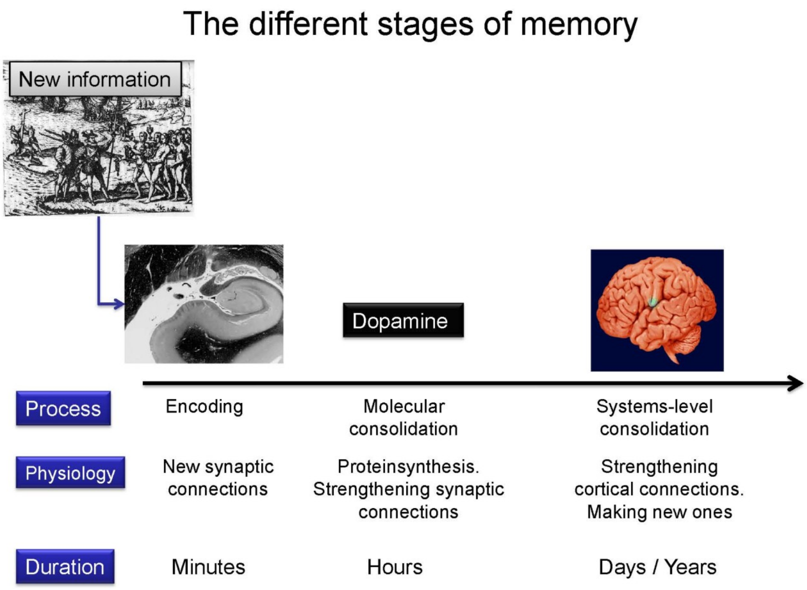
Memory for facts and events is called **declarative memory** and is what we usually mean by the every day use of the word memory. However, we actually remember many other things and these **non-declaritive memories** fall into several categories. One example is **procedural memory**, or memory for skills, habits and behaviours. We learn to play the piano, throw a Frisbee and tie our shoes and this is also clearly stored in the brain. Generally declarative memories can be accessed for conscious recollection and nondeclaritive memories cannot. Non declarative memory is therefore called implicit memory because it results from direct experience and declarative as explicit because it results from more conscious effort. However, as we shall see here these distinctions may not be as clear as we once thought and a number of hitherto unsuspected mechanisms may be at work in declarative memory—for example novelty and expectation.

How Events are Memorised

There are distinct phases of memory which may be separated into those lasting only a few minutes, those lasting many hours and beyond. Recent work (neuroimaging and neuropharmacology) has gone a long way to identifying and building upon earlier evidence that had been deduced using brain damaged patients, animal studies and classical cognitive techniques.

Memory formation involves the activation of pathways in the brain that are associated with the behavioural event, **encoding,** and if a number of conditions are met the pattern of this activation is **consolidated** by the strengthening of relevant connections and conserving the pattern of activity. This involves the synthesis of new proteins. Subsequently retrieval and reactivation of these traces will generate new associations using similar processes.





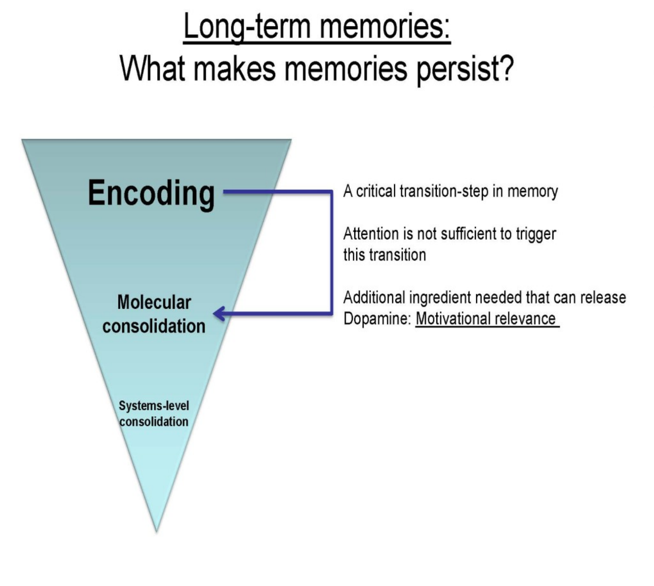
Long-Term Memory

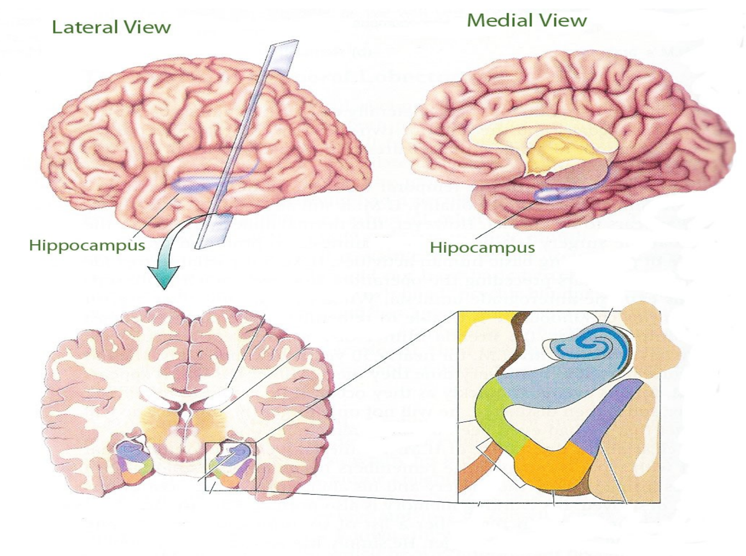
The vital step between the initial encoding of a memory and its long-term consolidation is complex and highly dependent on behaviour. Clearly it would not be sensible to consolidate everything we see and hear. As we saw earlier our evolutionary and genetic predispositions constrain our cognition in unexpected ways and similarly in memory the triggers for consolidation are, at first sight, counter intuitive.

Simply attending to a stimulus is not enough additional information is needed and this can be grouped under the general heading **motivational relevance.**

A huge amount of information has accumulated to demonstrate that reward process in the brain are associated with the release of the neurotransmitter Dopamine. Feeling "good" is highly associated with dopamine as work on illicit drugs, which have this effect, substantiates.

The hippocampus is a temporal lobe structure in the brain that early studies in brain damaged patients first identified as being crucial for the encoding and recall of episodic memory.

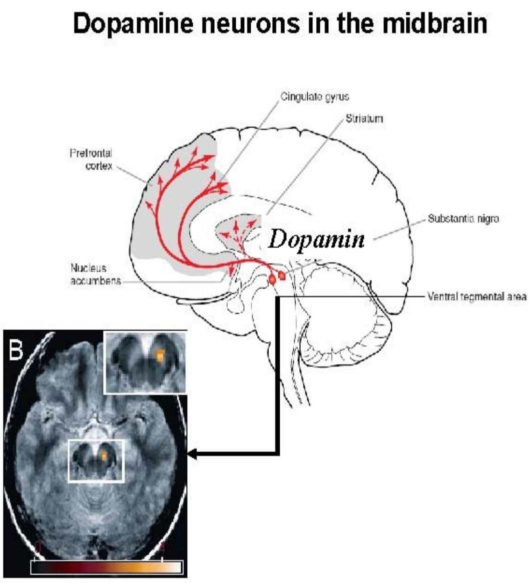




The role of the Hippocampus and Dopamine

Long-term potentiation in the hippocampus is a measure of the synaptic placticity associated with memory. Consolidation is prolonged by dopaminergic inputs. Reward increases the dopamine input into the hippocampus.

Human dopamine systems respond both to reward associated stimuli and more paradoxically simply to stimuli that are novel.



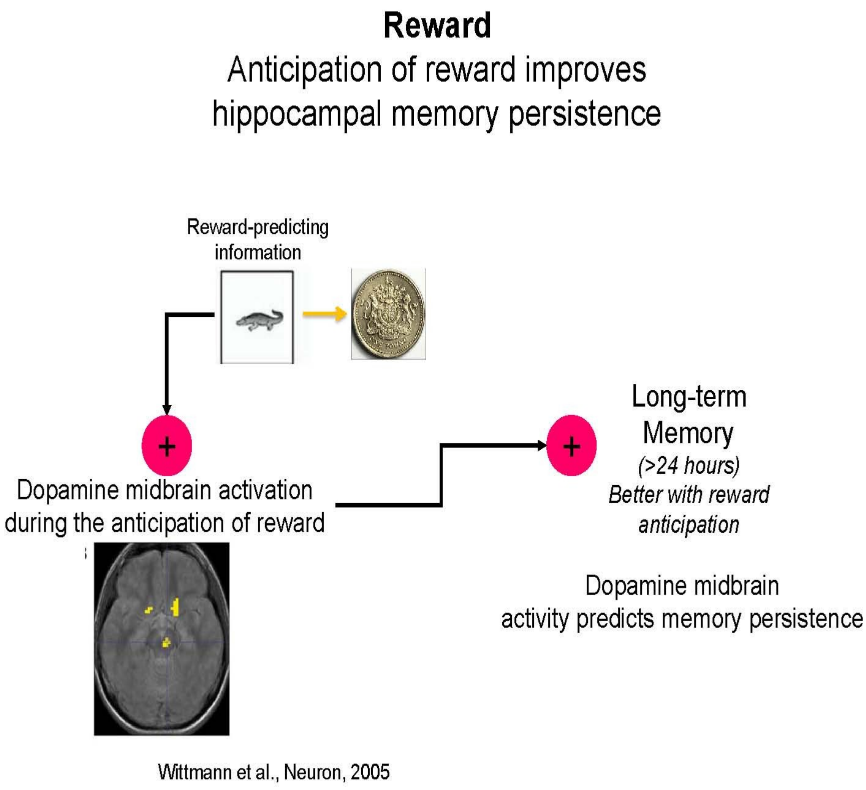
The past is hidden beyond the reach of the intellect in some material object (in the sensation which that material object will give us) which we do not suspect Proust 1927.

Reward and anticipation of Reward

Whittmann and her colleagues showed that in humans reward anticipation alone will boost recognition memory at a later date.

The investigation tackled the question by slicing together two fMRI tasks; one designed to evoke reward anticipation, the other to elicit memory encoding. They presented pictorial cues (living or non living things that signaled whether or not the subject could earn money in a subsequent task. Only reward predicting cues activated dopamine midbrain.

Those cues that were associated with rewards (i.e. reward anticipation) activated both the midbrain and the hippocampus and significantly enhanced the subsequent recall of the cues used in anticipation.

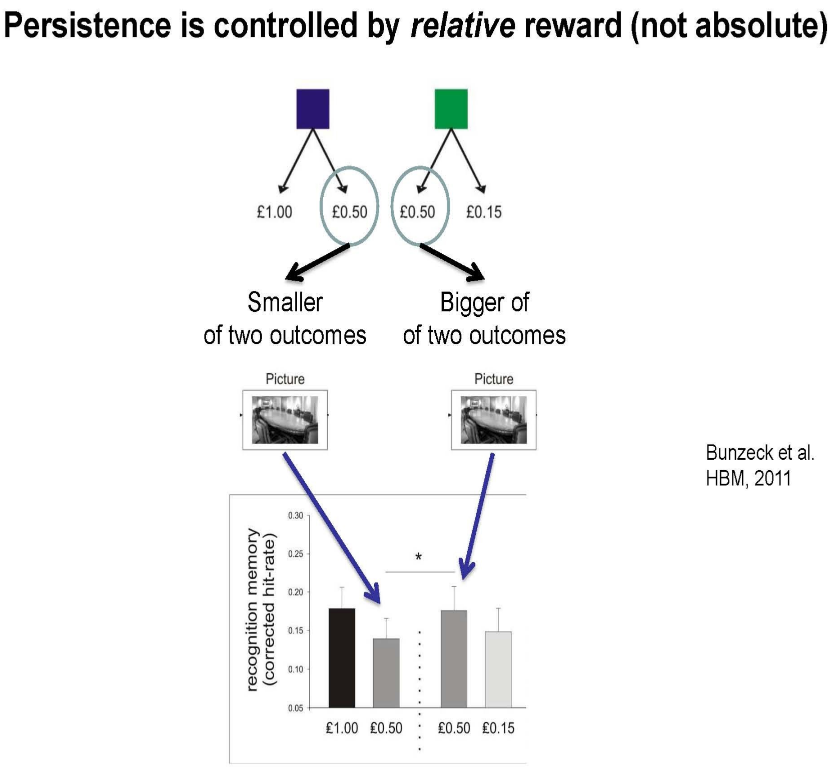


Remembrance of Past Rewards

We have all had the experience of powerful memories being evoked by smells (which may have been associated with rewards, particularly food). The taste of a tea-soaked Madeline unleashed the torrent of memories that came to fill Marcel Proust's volume: 'Ode to childhood'.

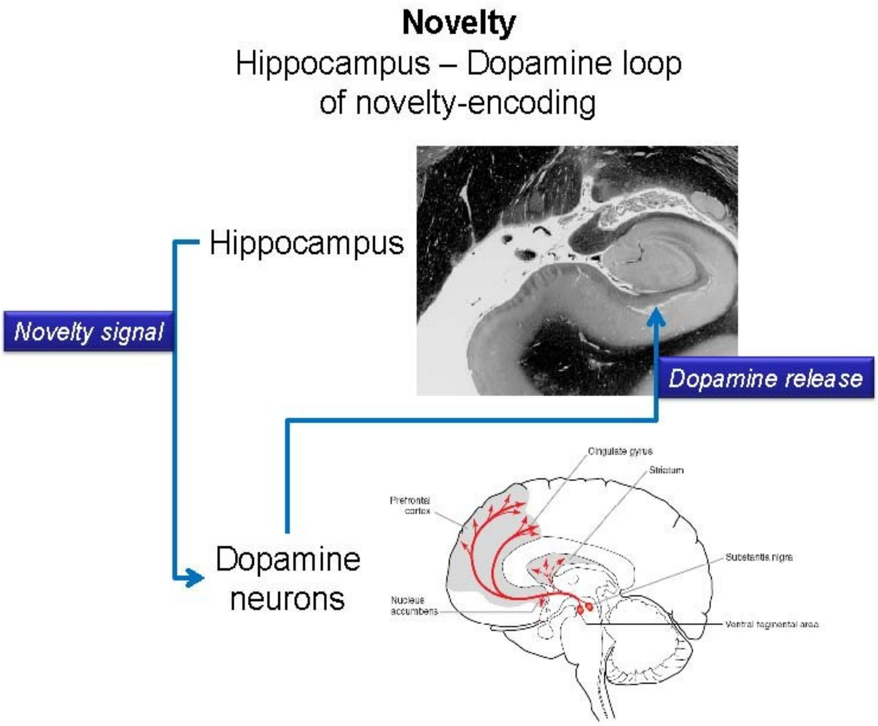
Proust noted that his memories were resurrected not by force of will, but by feeling of reward. The sub-cortical location of the modulatory processes above suggests that reward anticipation may be able to burn memories under the radar of consciousness. Similarly it is clear that the persistence of memory is not only controlled by anticipation of reward but the relative strength of that reward.

A huge amount of information may in this way be consolidated together for very good functional reasons. Take for example the tea-soaked Madeline. One, by this method, remembers not only the taste of the cake but also where it came from allowing you to repeat the experience!



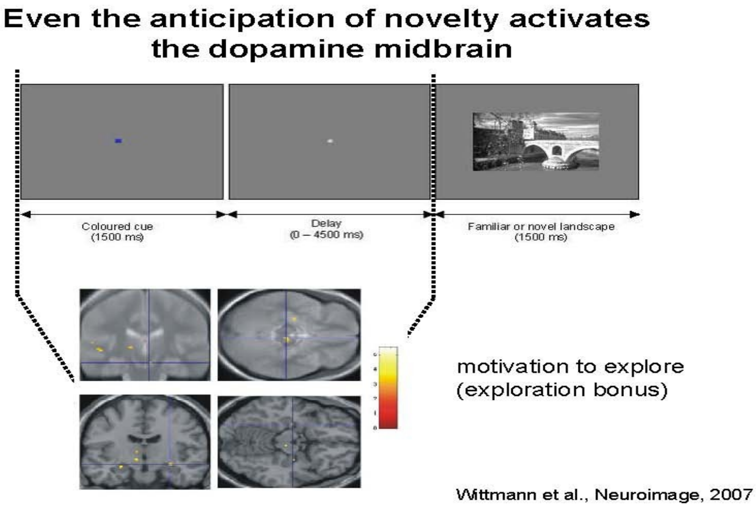
Generalization

Our ability to efficiently generalize past experience to new situations based upon hidden threads that cut across multiple events is intriguing. One possibility is that generalization is accomplished when it is needed, that means, when faced with a problem that requires generalization, to call into play effortful recall and manipulation and comparison of a range of events. However, there is a more adaptive and proficient way of achieving the same goal. This is to detect and encode generalizations as events around us unfold over time and store these generalizations as memories in themselves.



It is becoming clear that the midbrain dopamine releasing regions (substantia nigra and ventral tegmental area (SN/VTA) are activated both by stimuli that predict reward and by stimuli that are novel. A commonality in the effects of reward and novelty can be reconciled by the suggestion that novelty acts to motivate exploration of an environment to harvest rewards.

Novelty and its anticipation



When novel stimuli predict reward, reward expectancy is higher than when familiar stimuli predict reward. Even the anticipation of novelty, for example, the presentation of a blue square before the novel stimuli can in itself stimulate the dopamine midbrain. Why should novel stimuli have such an effect. If the novelty at hand is a new environment this potential for reward motivates the organism to physically move through the environment in order to explore it for rewards. Which in turn will be accompanied by forming declarative memories about the environment. This may explain why mid-brain stimulation involves both the VTA and the subtantia nigra—which is crucial for locomotion.

The Lure of the Unknown

We are constantly faced with a dilemma as to whether we explore new environments, new options, have new encounters and new contacts in the search for new sources of reward or remain in our familiar setting and exploit what is known to us.

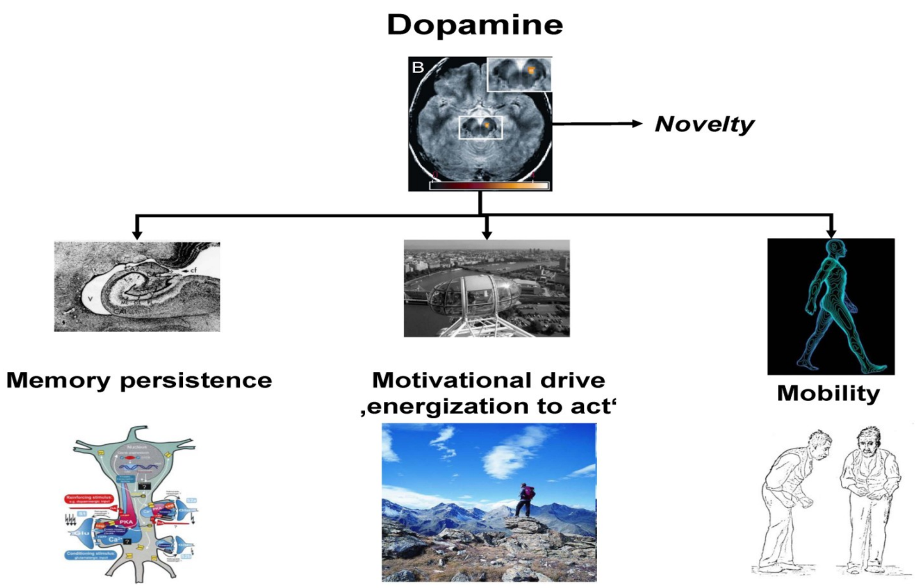
Dopamine and novelty-related dopamine releases biases this conflict from exploitation towards active exploration.

The link between dopaminergic mechanisms of reward processing and novelty may be a driving force behind our urge for innovation, discovery and active exploration.

Dopamine is not only linked then to reward and novelty but also to active behaviour. Although action and inaction can be seen to be logically independent of reward and punishment, physiologically they are not. Dopamine is strongly linked to active behaviour and rewards and inaction to punishment. In fact humans find it very difficult to learn to remain inactive in anticipation of reward.

Different personalities have inherently different responses to novelty as indeed do adolescents and adults (see Burnett later).

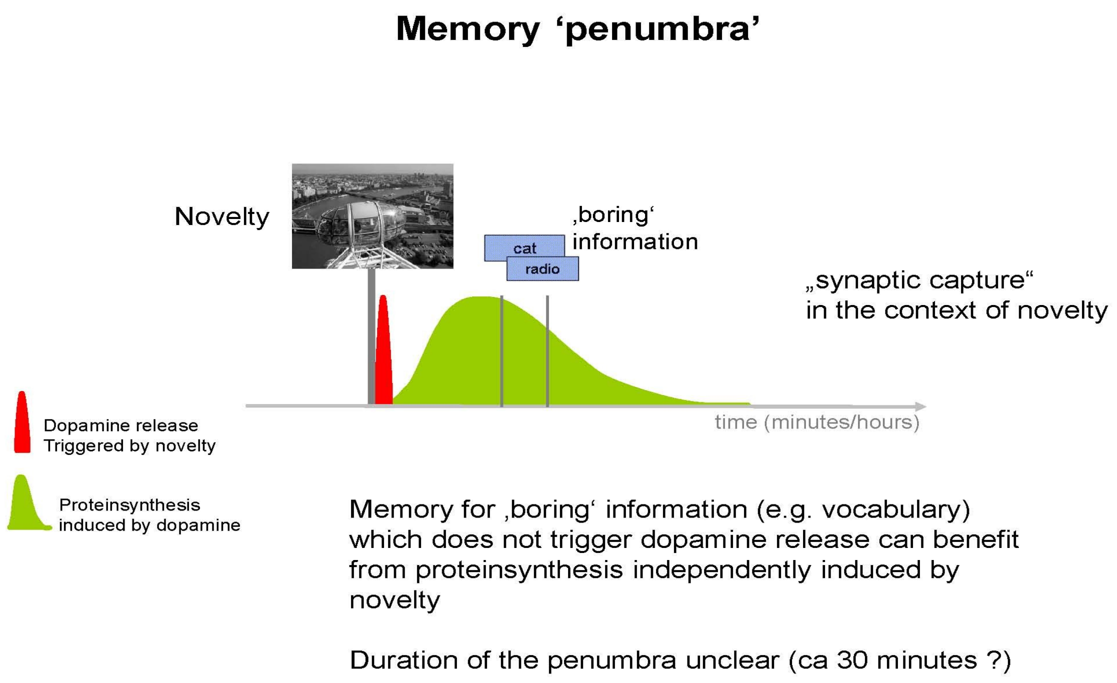
Novelty seekers need less reward. Memory persistence in individuals with high novelty-seeking scores benefits less from reward. They already have strong activation of the midbrain



Implications for Pedagogy

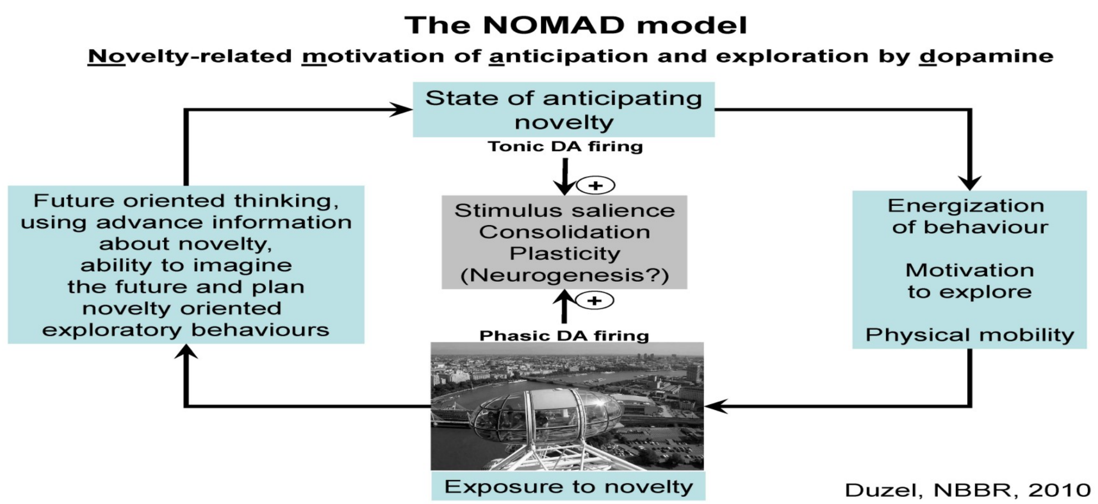
Novel information releases dopamine and this dopamine release induces protein synthesis in the hippocampus. These proteins remain available for a while and hence boring or repeated events that would by themselves not release dopamine can capture these proteins and undergo memory persistence.

Techniques to enhance dopamine release in a controlled and salient fashion will enhance consolidation. The human brain is inherently disinterested in repeated material. Hence learning French Vocabulary by repeating it will not induce Dopamine release. However browsing through a stimulating magazine before doing so will.



The NOMAD Model

Neuroscience can help us define and further establish motivational techniques some of which may not be intuitively obvious.



The Development of Social Cognition in adolescence

Dr. Stephanie Burnett Institute of Cognitive Neuroscience, University College London

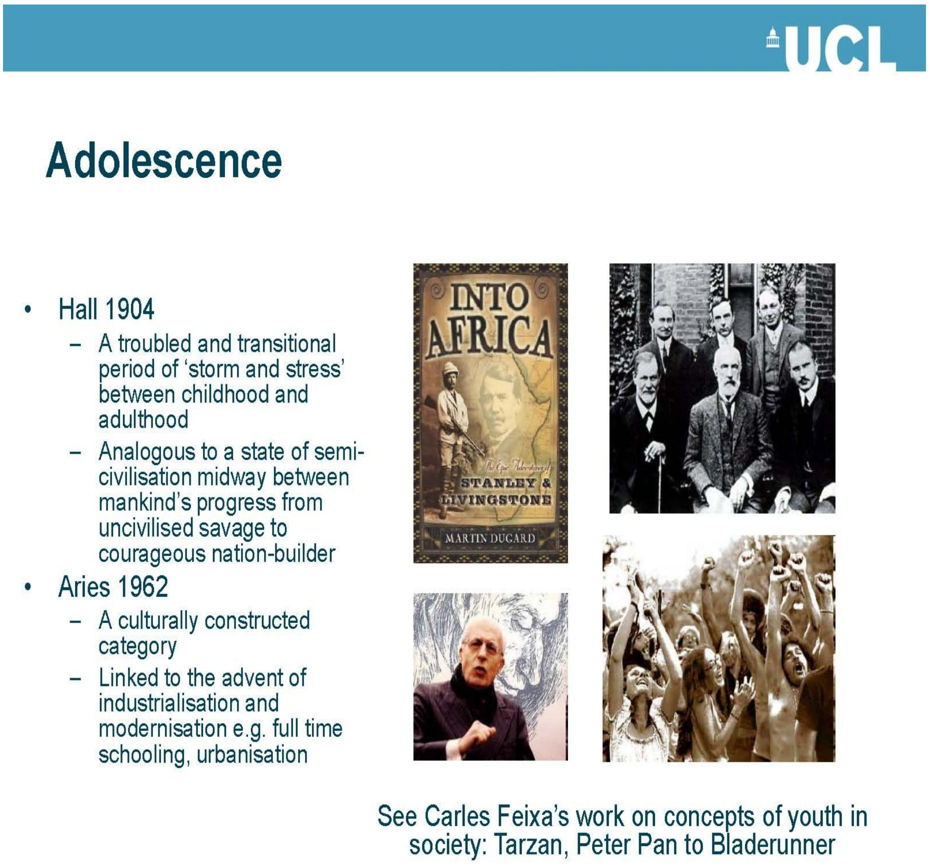
The period of adolescence has been termed a period of behavioural "storm and stress" certainly since the beginning of serious scientific study of social behaviour but quite clearly since before this.

A recent large-scale ethnographic study Choudhury (2010) suggests that a 'social stage intervening between childhood and adulthood in the passage through life' exists across most cultures. (Schlegel and Barry 1991).

Adolescents across species show comparable social behaviours:

Adolescent rodents show more social play than both younger and older animals.

Adolescent non-human primates show more affiliative behaviours towards peers, e.g. grooming, pair-sitting, huddling and dispersing into new social groupings.



Adolescent humans show some of these animal characteristics.

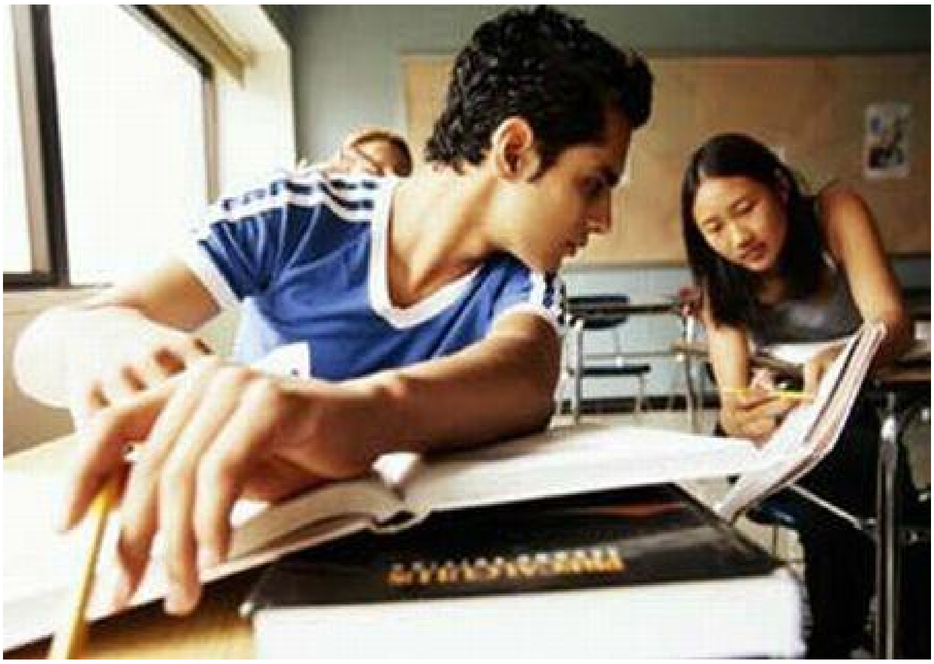
Adolescents spend more time with peers and less time with families.

- Feel stimulated and challenged when talking with peers

Peer relationships become more complex and hierarchically-organized

- Intense one to one relationships, small cliques, large crowds.

Emergence of adolescent micro-cultures with distinct linguistic pragmatics.

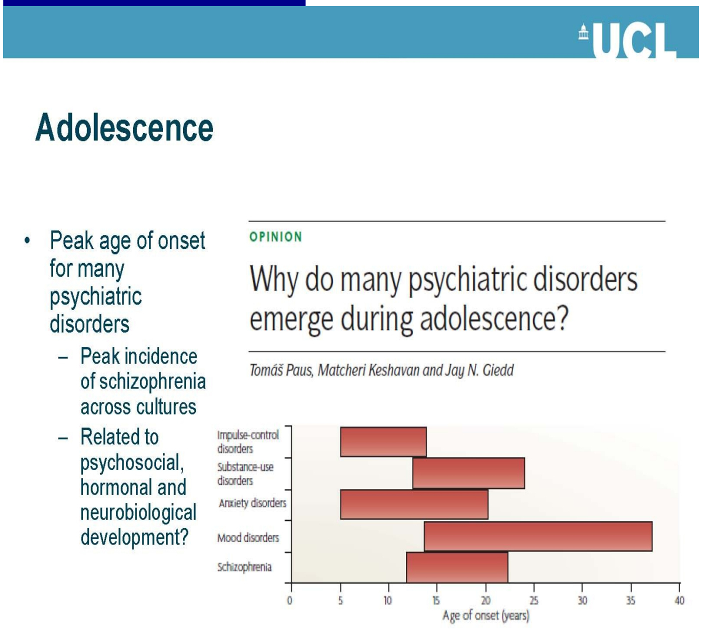


Vulnerability

The very structures that favour this explosion of social activity may also increase susceptibility to a range of psychiatric disorders .

Puberty—the transition to reproductive maturity– is a defining feature of adolescence. An important question is to determine the impact of pubertal changes in hormones upon neural development.

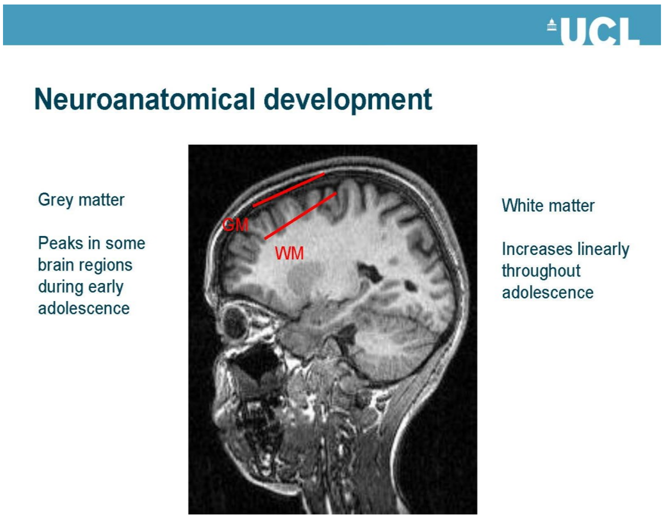
There is a very large effect of these hormones upon reward-related brain structures such as the nucleus accumbens and dopinergic pathways to the frontal cortex (see earlier).



Neuroanatomical Development

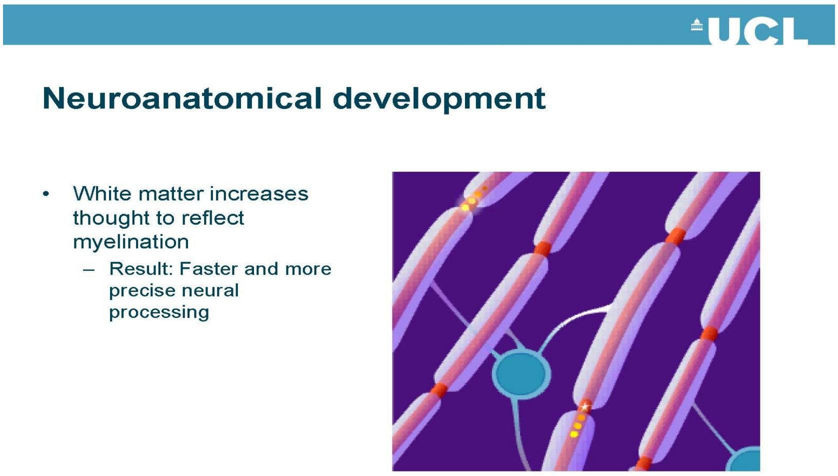
The advent of noninvasive brain imaging techniques, in particular magnetic resonance imaging (MRI), has enables investigation of the development of the living human brain. Developmental changes that have been delineated using MRI include alterations to the amount of gray and white matter and changes in white matter microstructure.

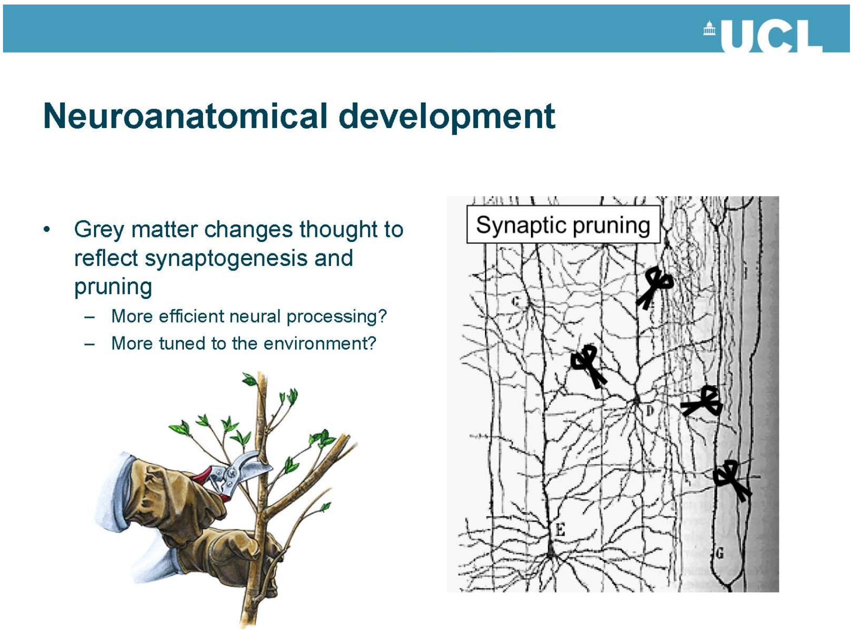
Many MRI studies show a steady linear increase in global white matter volume between childhood and adolescence with this increase slowing and stabilizing into adulthood.



Furthermore studies using fractional anisotropy (FA) in diffusion tensor imaging show changes in white matter microstructure. Studies consistently show an increase in FA during adolescence in the frontal lobes. The amount of cortical grey matter (its density, volume and thickness) changes during childhood and adolescence in a region-specific and nonlinear manner. Across much of the cortex gray-matter development conforms to an inverted U shaped trajectory, increasing in volume during childhood, reaching a peak in early adolescence and declining steadily into adulthood. Evidence suggests that the increase in volume is due to dendritic growth (projections allowing new connections between neurons) synaptogenesis (new connections between neurons) and the decline is synaptic pruning and indeed cell death which is an essential part of mature development. Many large areas of the cortex such as the visual cortex undergo expansion in early childhood followed by decline well before adolescence. It is of note that areas of the brain critical involved in social cognition particularly the frontal cortex only reach their peak early in adolescence and do not stabilize until the late 20s.

It should be noted that there is a significant sexual dimoirphism here with typically female peak development being attained 2 years before that of the male.





Behavioural implications

Immature prefrontal activity might hinder appropriate estimation of future outcomes and appraisal of risky choices.

This associated with increased activity in and development of subcortical motivation pathways (discussed earlier) results in an imbalance between top down control and bottom up motivational stimulus. The relative immaturity of the connections between incentive reward –systems, memory and experience and (hippocampus see earlier) and executive control (frontal cortex) seems to generate a programme of behaviour which is generally functionally beneficial i.e. allowing independence skills to be acquired and to increase success upon separation form the protection of the family.

Social Behaviour

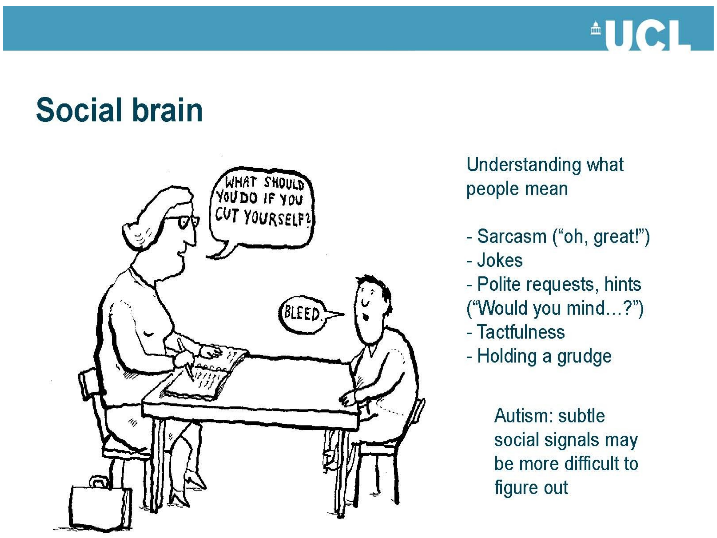
Human social preferences are apparent at a very early age. At only a few weeks after birth infants direct more smiles towards their caregiver and other humans than at inanimate objects. From around 1 year, infants deliberately engage and redirect the attention of the caregiver by pointing or vocalizing. By about 3 years of age children implement complex social tactics such as teasing, lying and saving face. Over the next few years, individuals learn to use these social tactics flexibly in different social situations. For example by 5-6 they can use deception to protect other people's feelings (telling 'white lies') in contrast to younger children who mainly use deception for self-serving reasons (e.g. to avoid punishment). A growing understanding of the self-conscious emotions (such as embarrassment, guilt and pride) at around the same age indicates that children are beginning to explicitly take other people's feelings into account in their emotional reactions to situations. By middle childhood concepts of fairness and justice show through in an emerging tendency to share resources.

Development of the mentalising system in Adolescence

During adolescence there is continued development of the ability to read emotions and of proficiency in taking on other emotional perspectives (stepping into other people's shoes) Similarly the ability to decide to ignore what others think that you should do (resisting peer influence) unfolds in the adolescent years.

For example it has been found that in a laboratory study of adolescents and adults playing a car-driving video game, with and without friends present, showed that when friends were introduced adolescents took significantly more risks.

Levels of risk taking did not increase for adult participants if their friends were watching and when adolescents were playing alone they showed the same level of risk taking as adults.

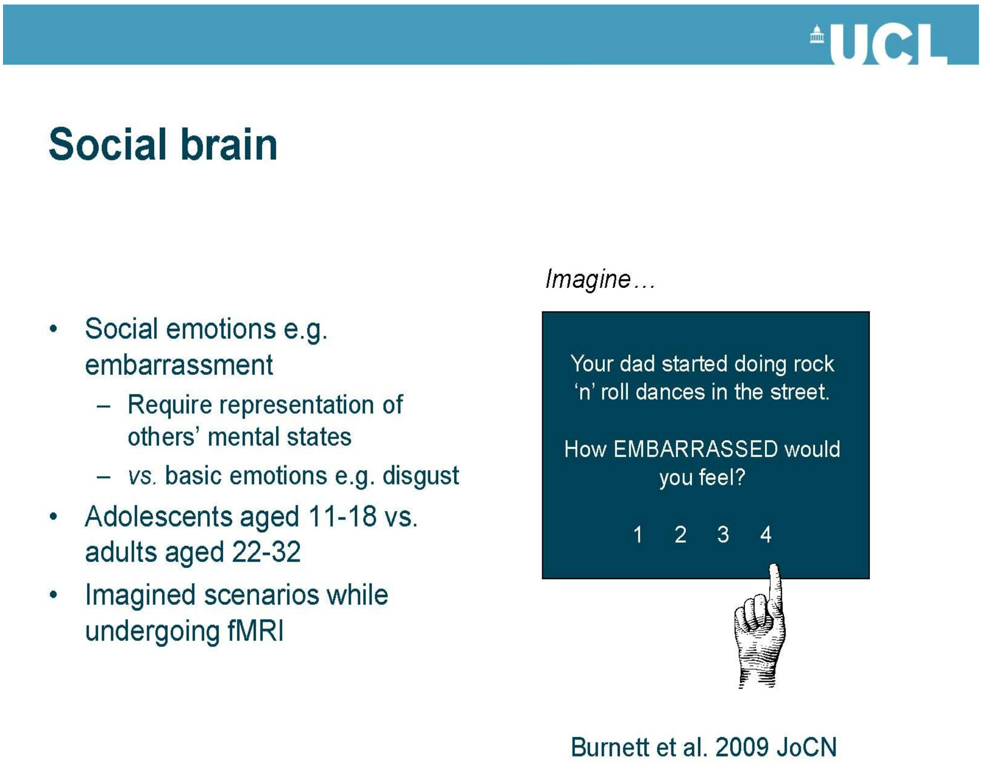


Social emotions

Social emotions such as embarrassment and guilt require the representation of another person's mental states, whereas this is not the case for basic emotions such as fear and disgust.

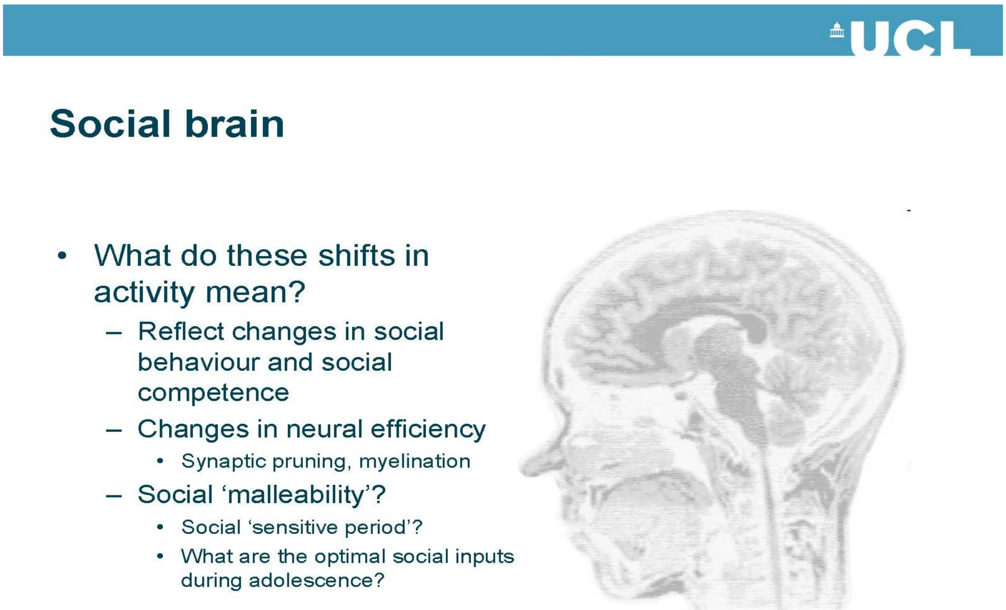
A mentalising system in the brain comprising of the medial prefrontal cortex, posterior temporal sulcus and the anterior temporal cortex is activated when subjects reflect on mental states such as intentions, beliefs and desires.

The functional connectivity between this system differs significantly between adolescents and adults suggestive of large changes in functional integration within the mentalising system during this period.



What do these changes in activity mean?

Generally these tasks produce activity in the mentalising system for adolescents which requires higher activity (as demonstrated by fMRI) in the medial pre frontal cortex and generally stronger co-activation of the mentalising system than adults. This may be because the maturing network in adolescents is less efficient in accomplishing this task. Continuing synaptic elimination and axonal myelination during adolescence within these regions of the brain involved in mentalising suggest this. Relative to adolescents adults might employ a more automatic, less explicit, mentalising strategy.



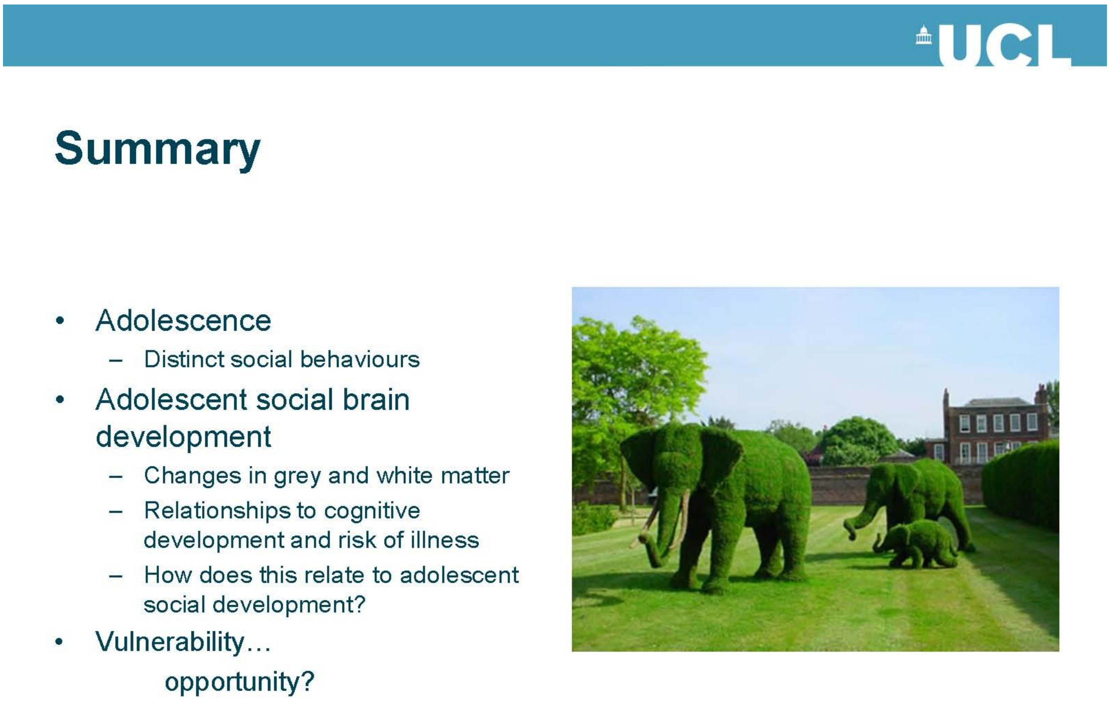
Implications for Pedagogy

We have seen that there are now emerging neural correlates to explain the range of behaviours normally shown in adolescence.

These have particular implications for developing the most effective motivational strategies and understanding particular behavioural vulnerabilities.

Should the curriculum include meta-cognition classes looking at for example, risk taking, peer influence, empathy, self-awareness and other awareness planning.

Disengagement with the educational system can lead to behavioural problems, social exclusion and crime and reduced employment prospects.



Bibliography

Abrahams, I. and Reiss, M. "Effective Practical Work in Primary Science." Primary Science 113 (2010): 26-27.

Beddington, J., Cooper,G.L., Field,J.,Goswami, U., Huppert,R.J., Jones, H.S., Kirwood,T.B.L., Sahakian,B.J., Thomas,S.M. "The Mental Wealth of Nations." Nature Vol 455 (2008): 1057-1060.

Blakemore, S. Byrnett,S. and Dahl,R. "The role of puberty in the developing adolescent brain." Human Brain Mapping 31 (2010): 926-933.

Bunzeck, N. Doeller,C. Dolan,R. and Duzel, E. "Contextual interaction between novelty and reward processing within the mesolimbic system." Human Brain Mapping (2011): 1-36.

Burnett, S. and Blakemore,S. "Functional connectivity during a social emotion task in adolescents and in adults." European Journal of Neuroscience 29 (2009): 1294-1301.

—. "The development of adolescent social cognition." Ann. N.Y. Acad. Sci 1167 (2009): 51-56.

Choudhury, S. "Culturing the adolescent brain, what can neuroscience learn from anthropology?" Social Cognitive and Affective Neuroscience 5 (2010): 159-167.

Corriveau, K., Goswami,U. and Thomson,J.M. "Auditory processing and early literacy skills in preschool and kindergarten population." Journal of Learning DSisabilities 43 (2010): 369-382.

DiSessa, A. "Towards and epistemology of physics." Cognition and Instruction 10 (1993): 105-225.

Duzel, E. Brunzexk,N. Guitart-Masip,M.and Duzel,S. "Novelety-related motivation of anticipation and exploration by Dopamine." Neuroscience and Biobehavioural Reviews 34 (2010): 660-669.

Friederici, A.D. "The neural basis of language development and its impairment." Neuron 52 (2006): 941-952.

Frith, U. "Brain Waves Module 2: Neuroscience implications for education and lifelong learning." February 2011.

Goswami, U. Gerson,D. and Astrue,L. "Amplitude envelope perception, phonology and prosodic sensitivity in children with developmental dyslexia." Read Writ 23 (2010): 995-1019.

Goswami, U., Fosker,T., Huss,M.,Mead,N. and Szucs,D. "Rise time and formant transition duration in the discrimination of speech sounds: the Ba-Wa distinction in developmental dyslexia." Developmental Science 14:1 (2011): p34-43.

Haworth, C.M. and Plomin,R. "Quantitiative Genetics in the Era of Molecular Genetics: Learning Abilities and Disabilities as an Example." Journal of the American Academy of Child and Adolescent Psychiatry (2011).

Humphrey, N.K. "The Function of Intellect." Growing Points in Ethology (1976): 303-317.

Jaeggi SM, Buschkuehl M, Jonides J, Shah P. "Improving fluid intelligence with training on working memory." Proc Natl Acad Sci U S A.105(19): (2008): 6829-33.

Kaise, M. Hilgetag,C.C., Kötter,R. "Hierarchy and dynamics of neural networks." Frontiers in Neuroinformatics (2010).

Kovas, Y. Haworth,M.A.,Dale,P.S. and Plomin,R. "The Genetic and Environmental Origins of Learning Abilities and Disabilities in the Early School Years." Monographs of the Society for Research in Child Development Vol.72 (2007): 1-160.

Lisman, J. and Grace,A. "The hippocampal-VTA loop:Contolling the entry of information into long-term memory." Neuron 46 (2005): 703-713.

Mischel, W. Shoda, Y. Rodriguez, M.I. "Delay of gratification in children." Science 244 (4907) (1989): 933-938.

Plomin, R., Haworth,C.M. and Davis,O.S. "Common disorders are quantitiative traits." Nature Rev. Genet (2009): 872-878.

Schlegel, A. and Barry,H. Adolescence: An Anthropological Enquiry. New York: Free Press, 1991.

Wahlstrom, D. Collins,P. White,T. and Luciana,M. "Developmental changes in dopamine neurotransmission in adolescence: Behavioural implications and issues in assessment." Brain and Cognition 72 (2010): 145-159.

Wittmann, B.V. Schott,B. Guderian,S. Frey,J. Heinze, H. and Duzel, E. "Reward-related fMRI activation of dopaminergic midbrai is associated with enhanced hippocampus-dependent long-term memory formation." Neuron 45 (2005): 459-467.

Woollett K, Spiers, H.J and Maguire, E.A. (2009). "Talent in the Taxi: a model system for exploring expertise." Pil. Trans. R.Soc. B 364(1522) 1407-1416 (2009).