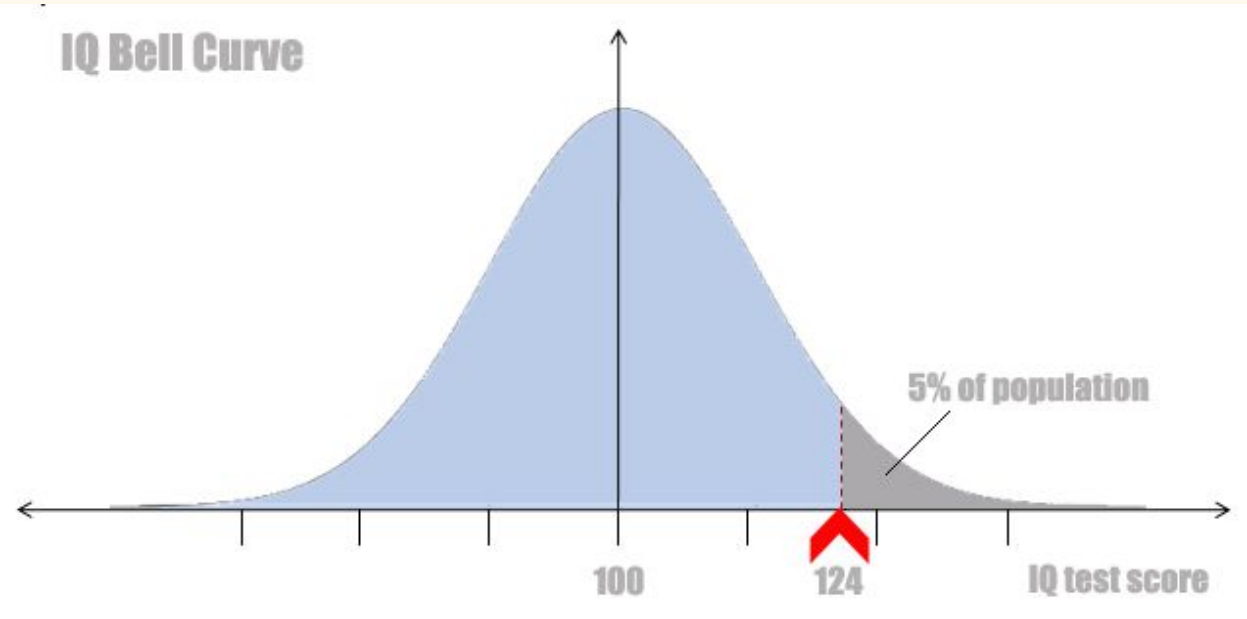
HRP Lab 2018
CAMBRIDGE, UK

PSYCHOMETRIC
IQ AUGMENTATION 2



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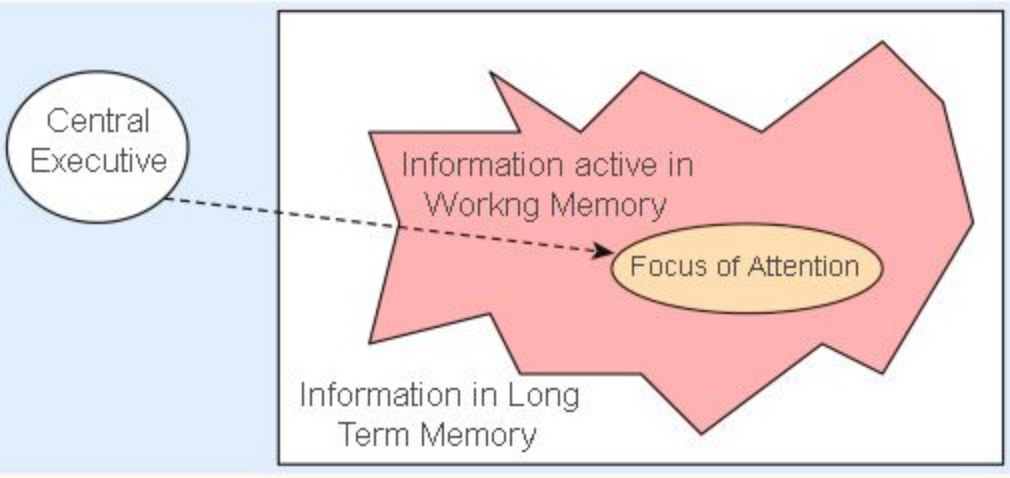
BRAIN BASIS OF INTELLIGENCE

Attention Control & Intelligence

According to research (ref1, ref2), holding useful information online in the 'mental workspace' of working memory (***Gwm***) depends on **attention control.** Your 'attention spotlight' activates contents from **long-term memory** (LTM), such as your factual knowledge or skills, that you can then apply while you problem solve, make a decision, comprehend something and so on.

The source of this attention-control is called the brain's **Central Executive** because it exerts 'top-down' control of **goal-directed** cognition and behavior. A brain's 'higher level' goal might be to 'understand this eBook'!

This is shown in this simplified model here. The activated region can be considered to be your mental workspace. What you are currently attending to in this workspace is the focus of attention, and this depends on 'central executive' goals and intentions.



Cowan's model of working memory (1988) (ref)

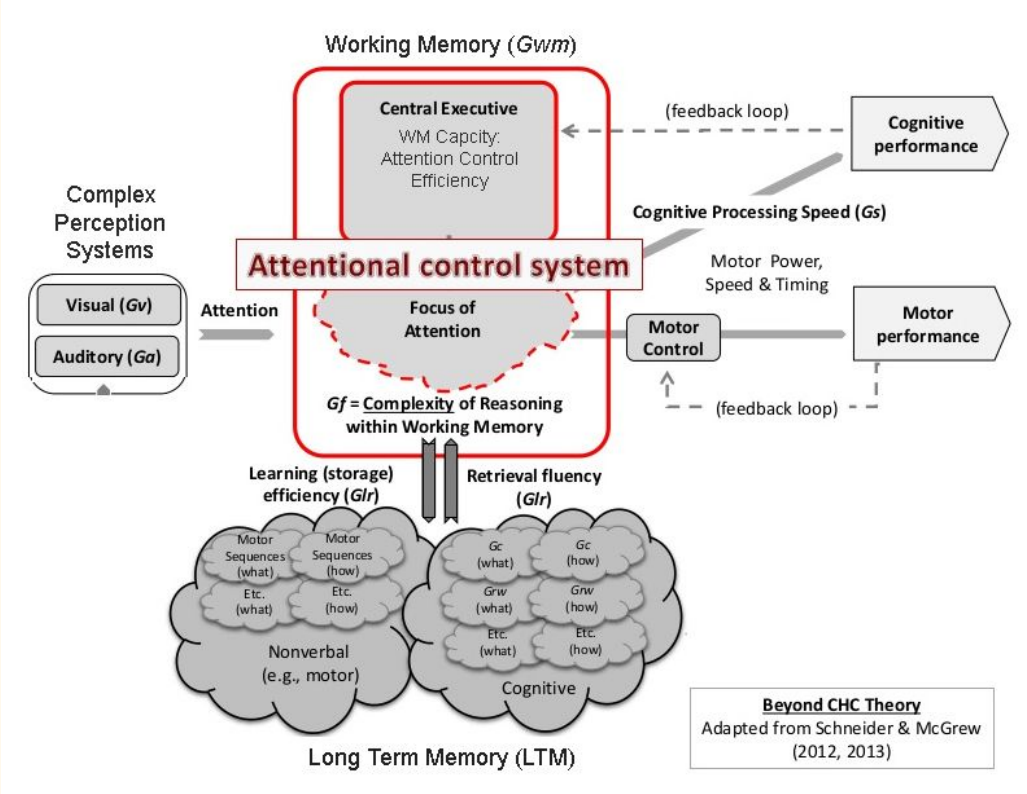
How does attention control and working memory relate to psychometric IQ?

Tying all the threads together discussed in the previous eBooks, Schneider and McGrew have formulated an **Attention Control System** model of general intelligence (***g***).

Working memory and attention control act as a **hub** for all abilities tested in IQ tests, and because the attention spotlight and mental workspace they are limited in capacity (unlike long term memory) they are also an information processing **bottleneck** in cognitive and motor performance. The greater our WM efficiency and capacity, the less restricting the bottleneck, and the more capacity we have for intelligent information processing and performance.

So clearly, increasing the size of our working memory capacity, and improving our attention control, will benefit general intelligence. This is the rationale behind brain training software such as i3 Mindware.

Schneider and McGrew's Attention Control System model of intelligence is shown below with the broad ability factors of intelligence (***Gv, Ga, Gwm, Gf, Glr, Gc, Grw, Gs***) all we looked at in *Psychometric IQ Augmentation 1* labelled.



Schneider & McGrew's Attention Control Syste m Theory of Intelligence (2012/2013) (ref)

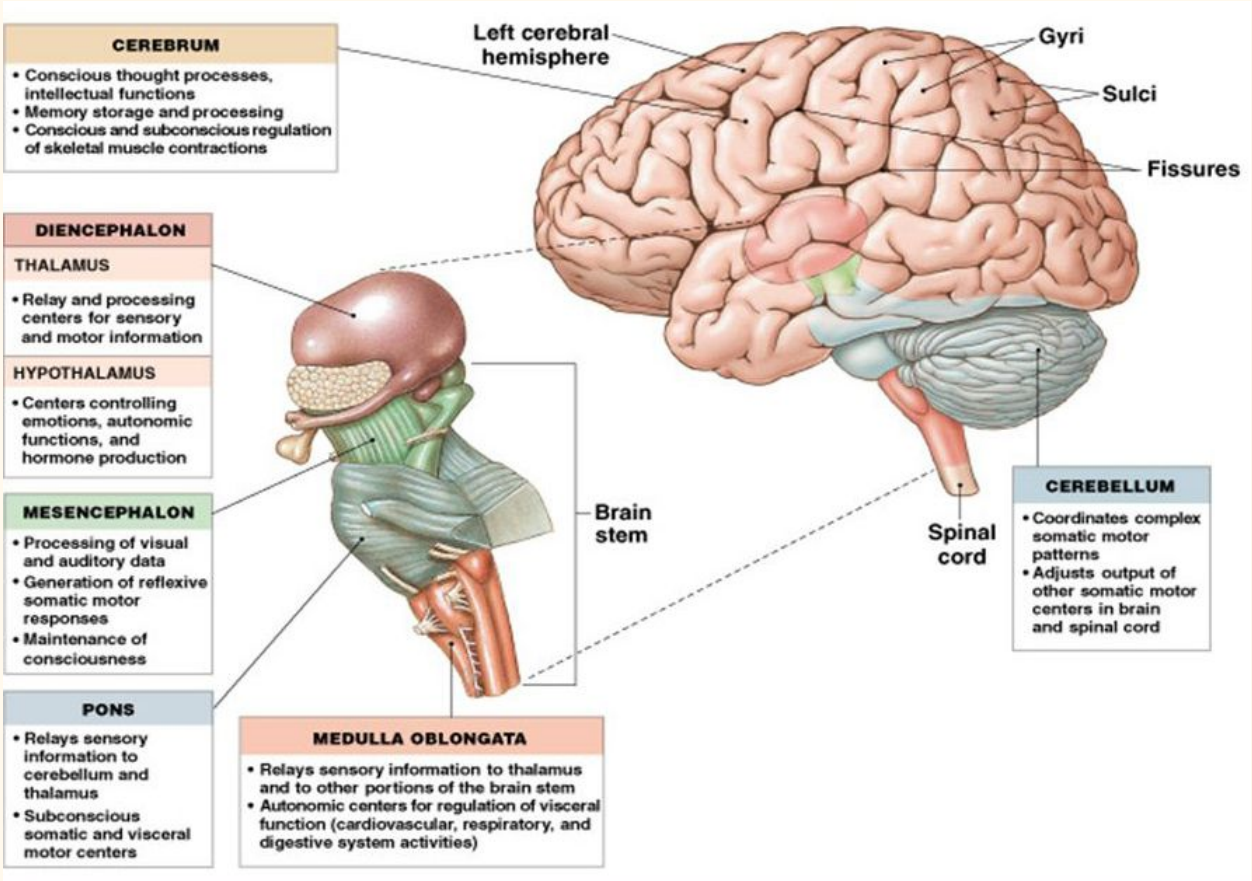
According to this model that we use, Fluid reasoning(***Gf***) (measured by matrices IQ tests) is the *complexity of reasoning and problem solving within working memory*.

Gf is closely bound to the efficiency of attention control such as focus and inhibition of distractors. ***Gf*** a system for *flexible problem solving and adaptation to new task-demands - particularly in the face of interference* (ref). ***Gf*** should thus not be just thought of as just abstract reasoning ability.

So how does the **attention control - working memory - fluid intelligence hub** of our general intelligence relate to our brain?

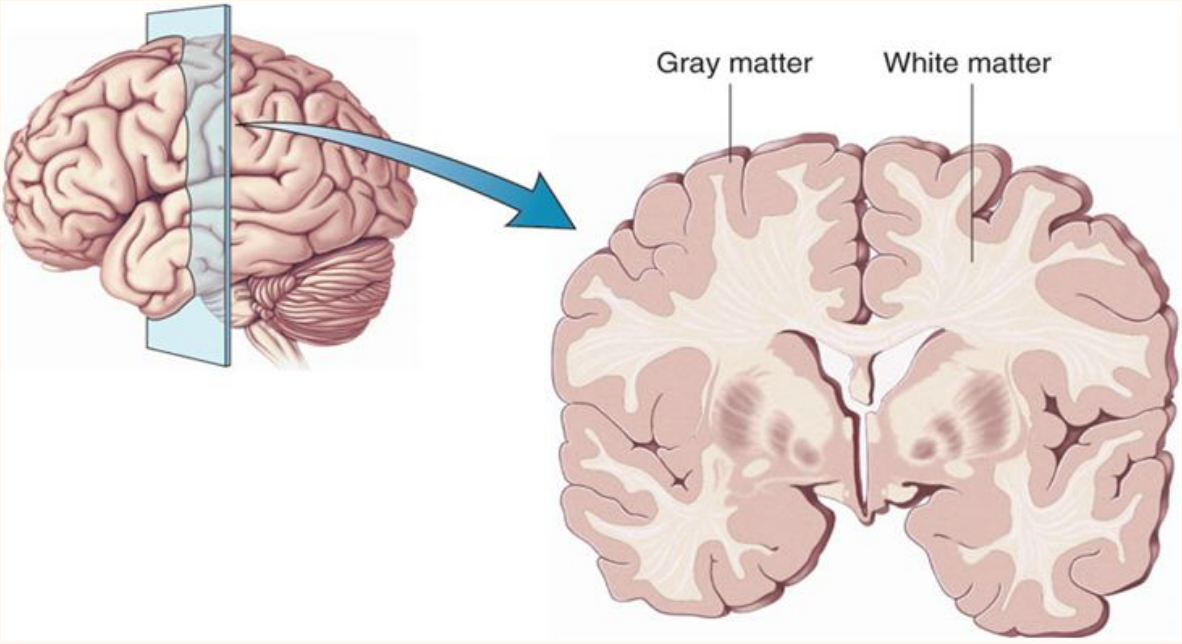
Human Brain Anatomy

The human brain has major divisions with different functions shown in this diagram here. The cerebrum and cerebellum have two halves (left and right side 'hemispheres'). The diagram shows the left hemispheres of these two divisions - the cerebellum is at the back of the brain.



IQ tests measure cognitive abilities based in the **cerebrum** which contains the large **cerebral cortex** (both left and right hemispheres) as well as **subcortical** structures such as the hippocampus and basal ganglia.

The cerebral cortex has an outer zone of neural tissue called **grey matter** (the 'cortex') which is folded all over to increase surface area - this is what you typically see in external views of the brain. It's in the grey matter where you find the complex **brain cell (neuron) circuitry** that subserves our memory, intelligence and awareness. Beneath the brain's grey matter is **white matter** where neurons relay electro-chemical signals between different areas of cortex and the rest of the brain. Here is a slide of a slice taken through the middle of the brain, showing the cerebrum's grey and white matter.

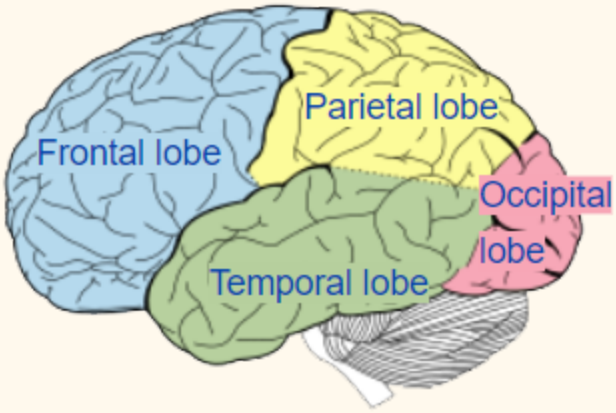


The human cerebral cortex contains approximately 15–33 billion neurons, each connected by synapses to several thousand other neurons.

Over the course of evolution, the human brain has seen a massive expansion of the cerebral cortex, especially the prefrontal cortex shown here.

Prefrontal cortex

The prefrontal cortex is the seat of executive control, fluid intelligence and working memory. It is part of the frontal lobe. The **lobes** of the cerebral cortex include the frontal (blue), temporal (green), occipital (red), and parietal (yellow) lobes.

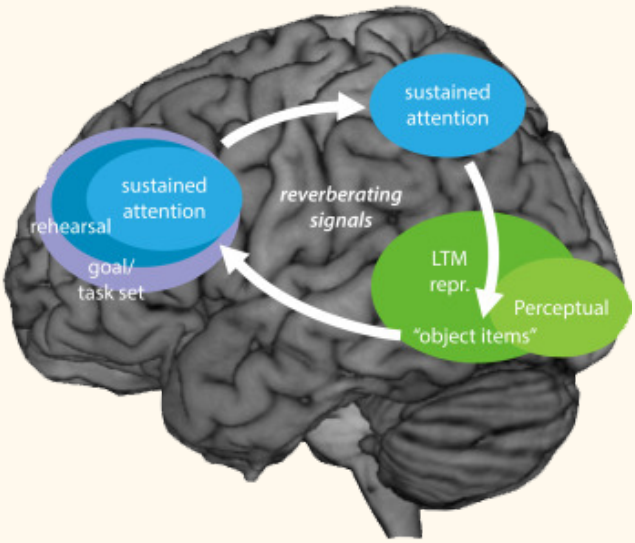


Different cortical lobes are the seat of different brain functions.

So much for the introduction to brain anatomy 101!

The Parietal-Frontal Integration Theory of Intelligence (P-FIT)

Different brain regions interact when we use our working memory including 'executive' regions in the **prefrontal cortex** and **parietal cortex** (shown in blue) as well as regions specialized for long term memory representations (shown in green) in the temporal and occipital lobes.



From Eriksson et al, 2015 (ref)

Brain imaging studies have shown time and again that tasks involving controlled attention, working memory or fluid reasoning (*Gf*) are linked to neural signalling in the **prefrontal** and **parietal** lobes of the brain.

These findings have resulted in the influential **Parieto-Frontal Integration Theory of intelligence (P-FIT)** (ref).

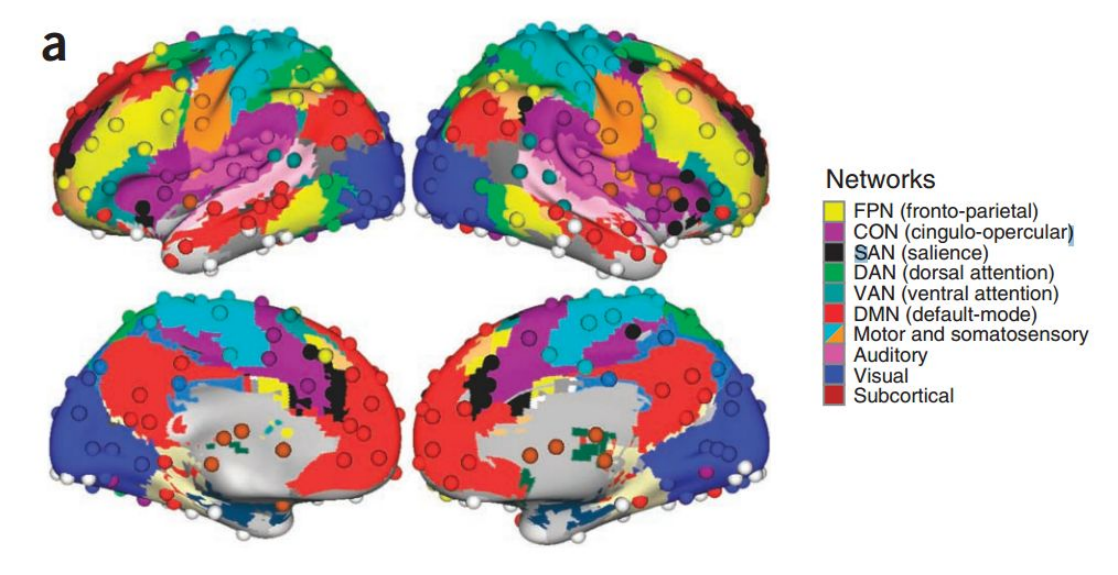
According to P-FIT, information processing within this network during IQ demanding tasks is directly related to individual differences in general intelligence (***g***). Differences in the functioning of this network underlie differences in IQ test scores.

The P-FIT theory of intelligence can be understood as the **biological basis of the Attention Control System model of intelligence (*g*)** that put working memory and attention control at the center of psychometric IQ. They are consistent with each other, and mutually support each other in terms of the evidence - both in psychometric testing and brain imaging.

The Fronto-Parietal Network Hub

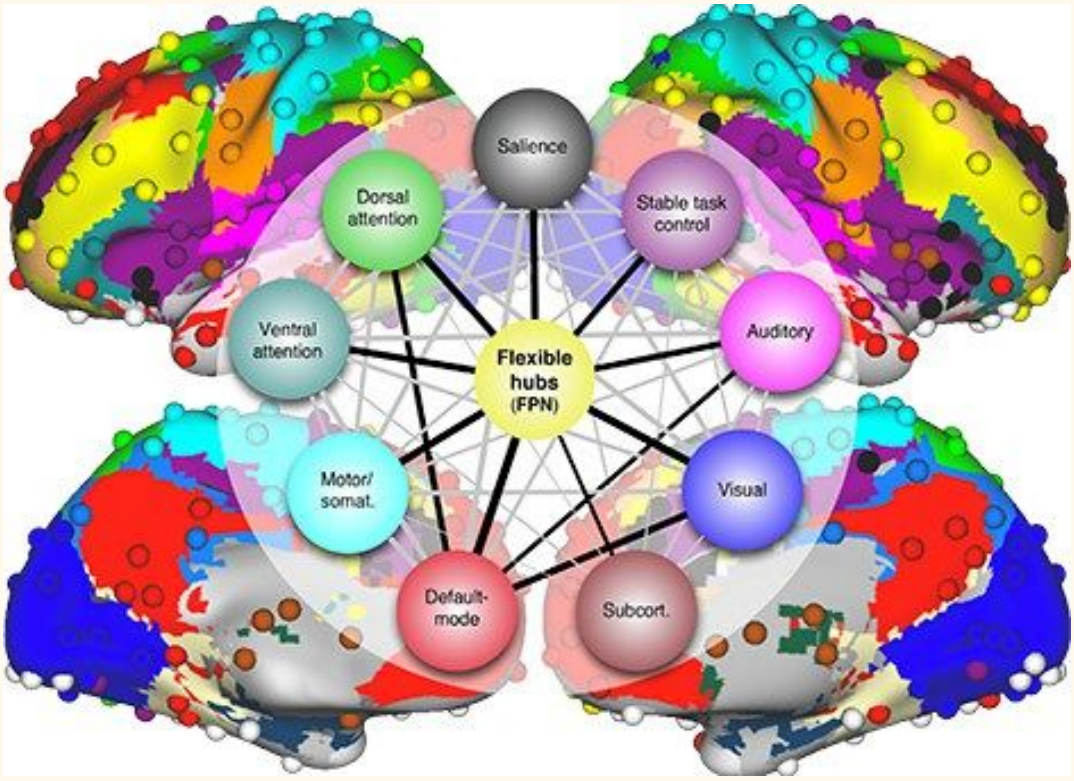
The P-FIT theory is based on looking at brain activity when ***actively*** doing IQ-demanding tasks such as doing math reasoning.

There is another neuroimaging research tradition (ref 1, ref 2) that looks at spontaneous brain activity of brain regions ***at rest*** - when individuals being scanned are not doing any tasks. This approach has revealed a number of 'resting state' functional networks in the brain - color coded in the figure below.



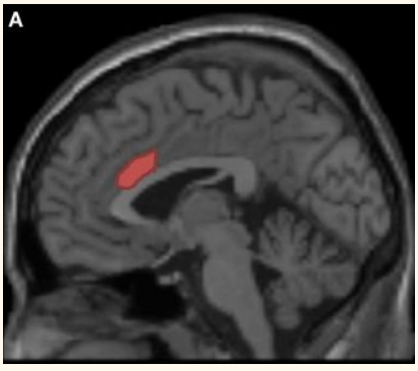
Functional Power et al., 2011

One of these networks called the Fronto-Parietal Network (FPN) shown in yellow above and below is connected to other networks like a hub in a wheel.



The Fronto-Parietal Network (FPN) Hub (Ref)

Consistent with P-FIT, the Fronto-Parietal Network includes communicating regions of the prefrontal cortex and parietal cortex - as well as a region of the cingulate cortex shown in red in this fMRI brain scan. The cingulate cortex is located right in the midline of the brain next to the division between the left and right hemispheres.



Being a central 'hub' of brain networks enables it to have top down **executive control** - flexibly shunting information flow across the other networks depending on the task at hand (ref). In this way the PFN allows for quick, intelligent adaptation to new cognitive demands, overcoming automatic rigid habits.

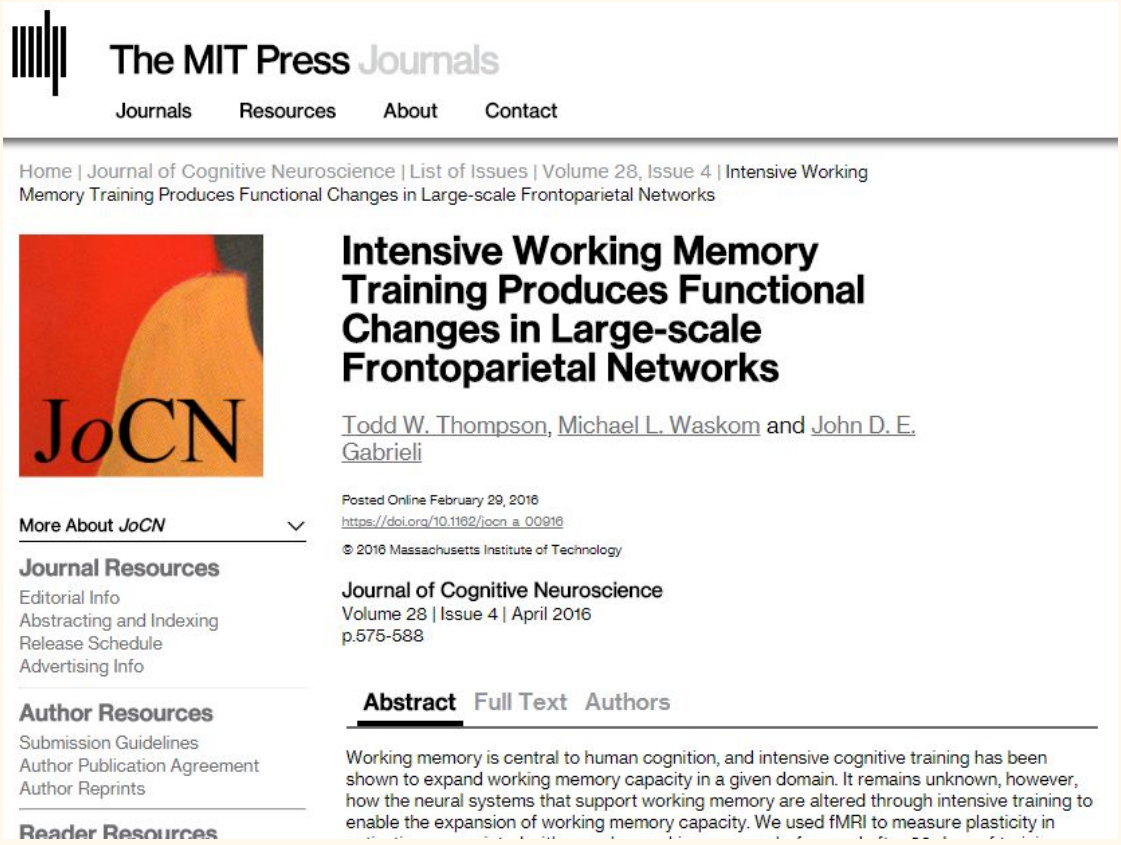
In this network, the **prefrontal cortex** holds rules (e.g. for fluid reasoning) in working memory, shifts attention depending on what we need to focus on, and makes decisions for action. **Parietal cortex** provide an 'salience map' of what is important in the flow of information through our senses as well as learned associations in long-term memory (review). The **cingulate cortex** detects conflict in potential responses (e.g. in the Stroop task or when there are distractions) and send this information to the prefrontal cortex to resolve.

The FPN network works nicely with the P-FIT theory of intelligence discussed above.

Brain Training: P-FIT & The Fronto-Parietal Network

Working memory brain training (e.g. implemented in i3 Mindware) is known from multiple studies (ref 1, ref 2, ref 3) to result in neuroplasticity change in the the Fronto-Parietal Network. Some of this evidence is listed below. For a full review follow this link.

1. Working memory brain training affects activity in the Fronto-Parietal Network. **Functional connectivity** within this network increases following training, and the magnitude of increased connectivity is tied to improvements in task performance (ref).

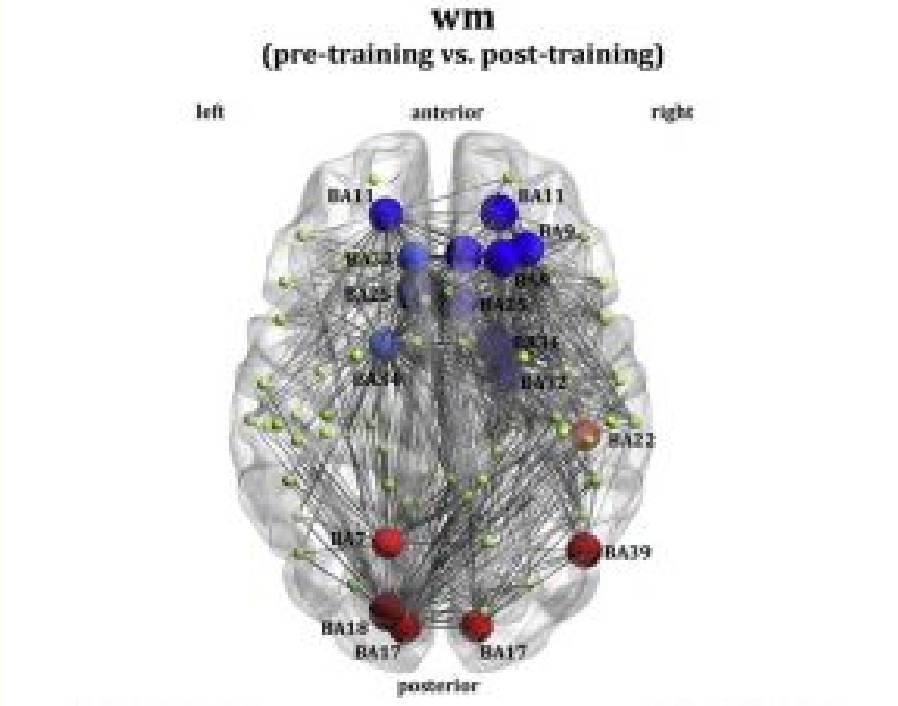


Journal article link

2. Working memory training **increases grey matter volume** in the Fronto-Parietal Network (ref).

3. Working memory training results in **neuroplasticity change in dopamine receptors** in the Fronto-Parietal Network. The neurotransmitter dopamine is very important for working memory and working memory performance is affected by dopamine levels in the prefrontal cortex, with dopamine release observed during the performance of working memory tasks (ref1, ref2).

4. Working memory training results in increased network efficiency within the Fronto-Parietal Network (ref).



Pre-training vs post WM-training FPN network efficiency (ref)

Summary

In this eBook we have looked at the way attention control, working memory and fluid intelligence are all closely related as a 'central hub' for our general intelligence (***g***). I have provided a little tutorial on human brain anatomy and introduced the Parieto-Frontal Integration Theory of Intelligence (P-FIT) as well as the Fronto-Parietal Network (FPN) - the brain hub underlying intelligence and top-down executive control. We then looked at evidence for the neuroplasticity benefits of working memory based brain training (such as i3 Mindware) on this central hub of intelligence.