PSYCHOMETRIC
IQ AUGMENTATION

IQ Bell Curve

5% of population

100   124   IQ test score

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1. WHAT IS GENERAL INTELLIGENCE?

Definitions

A good cognitive science definition of general intelligence is:

> *". . . that facet of mind underlying our capacity to think, to solve novel problems, to reason and to have knowledge of the world."* **M. Anderson**

Note that the definition emphasizes **abstract** cognitive processes: thinking and reasoning and knowledge as mental models. This op-ed statement signed by fifty-two researchers in the field (ref) extends this idea to include learning and being 'switched on':

> *A very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings —"catching on," "making sense" of things, or "figuring out" what to do.*

This 20+ year old definition still holds, but over the past 20 years different working definitions have evolved in different fields.

From an **applied IQ** perspective comes and emphasis on productivity, captured by:

> *"An intelligence is the ability to solve problems, or to create products, that are valued within one or more cultural settings."* **H. Gardner**

> *". . . I prefer to refer to it as 'successful intelligence.' And the reason is that the emphasis is on the use of your intelligence to achieve success in your life. So I define it as your skill in achieving whatever it is you want to attain in your life within your sociocultural context"* **R. Sternberg**

From the **artificial intelligence (AI)** movement comes an emphasis on efficient **goal** achievement, captured in these definitions:

> *"Achieving complex goals in complex environments."* **B. Goertzel**

> *"Intelligence is the ability to use optimally limited resources – including time – to achieve goals."* **R. Kurzweil**

However intelligence is defined in real-life settings, from a scientific point of view, it needs to be **measured**, and the science of measuring cognitive abilities is called 'psychometrics'.

It is the psychometric tradition that gives us our much-loved IQ tests such as the WISC-IV, WJ-IV and WAIS-IV, and the host of aptitude and ability tests that play an important selecting and streaming role in educational and professional development.

Psychometric IQ
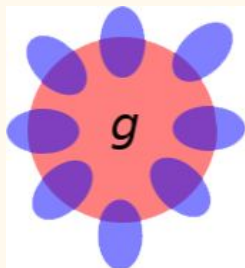
Our numeric IQ level is what psychometric IQ tests measure. While people have different cognitive strengths and weaknesses (e.g. language, math, visuospatial), **correlations** (statistical links) between measures of these abilities show us there is a common component to all of them. This underlying component is called *g* (general intelligence). Standardized **full-scale** IQ tests are designed to measure *g*.

Further statistical analysis shows that test scores on different types of cognitive ability tests tend to cluster or group in certain ways, revealing a number of underlying 'broad ability' factors of intelligence - such as quantitative and general knowledge abilities.

Individuals can differ not just on how they score compared to others on their overall intelligence (*g*) but also on different broad abilities which we'll look at below.

Individual Differences in Test Scores

"Each mind has its own method." Emerson

"Minds differ more than faces." Voltaire

As argued by the Director of the Institute for Applied Psychometrics, Kevin McGrew, a major purpose of psychometric testing: to appreciate *the individual difference terrain or landscape of each individual's personal abilities*. In other words, to understand each person's **unique personal profile** - their cognitive peaks (potentialis, capacities, strengths) and valleys (weaknesses, deficiencies), to design programs to allow them to reach their fullest potential.

This is the primary aim underlying the development of IQ increasing apps such as i3 Mindware.

Another purpose of psychological testing is **selection and streaming** - for example testing for college admissions or job selection.

The CHC Theory of General Intelligence (*g*)

The CHC theory of intelligence ([ref](#)) is based on the analysis of hundreds of data-sets and is the most widely accepted taxonomy (classification) for intelligence..

There are **three strata** or levels. General intelligence (*Spearman's g* or simply *g*) is at the top (Stratum 3), with **9 broad ability domains** below that (Stratum 2), and more than 70 'narrow' abilities (Stratum 1) below that.
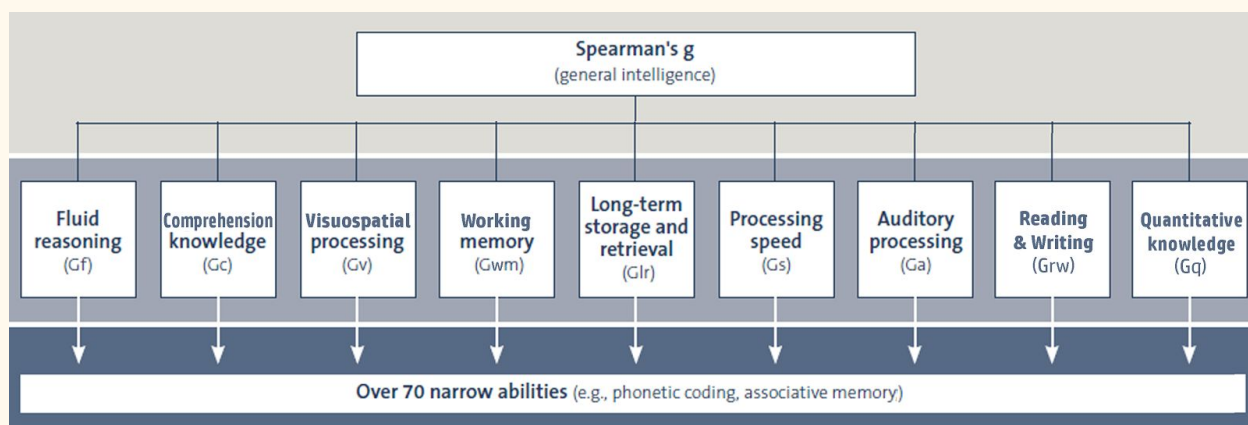
Individual differences in overall intelligence (*g*) as well as broad ability domains are measured by the IQ subtests full-scale, **professionally administered IQ tests** such as the WISC-V or WJ-IV.

Here is a diagram showing how the broad ability domains of intelligence have been measured by subtests of the WJ-III IQ test (the subtest titles are on the left).
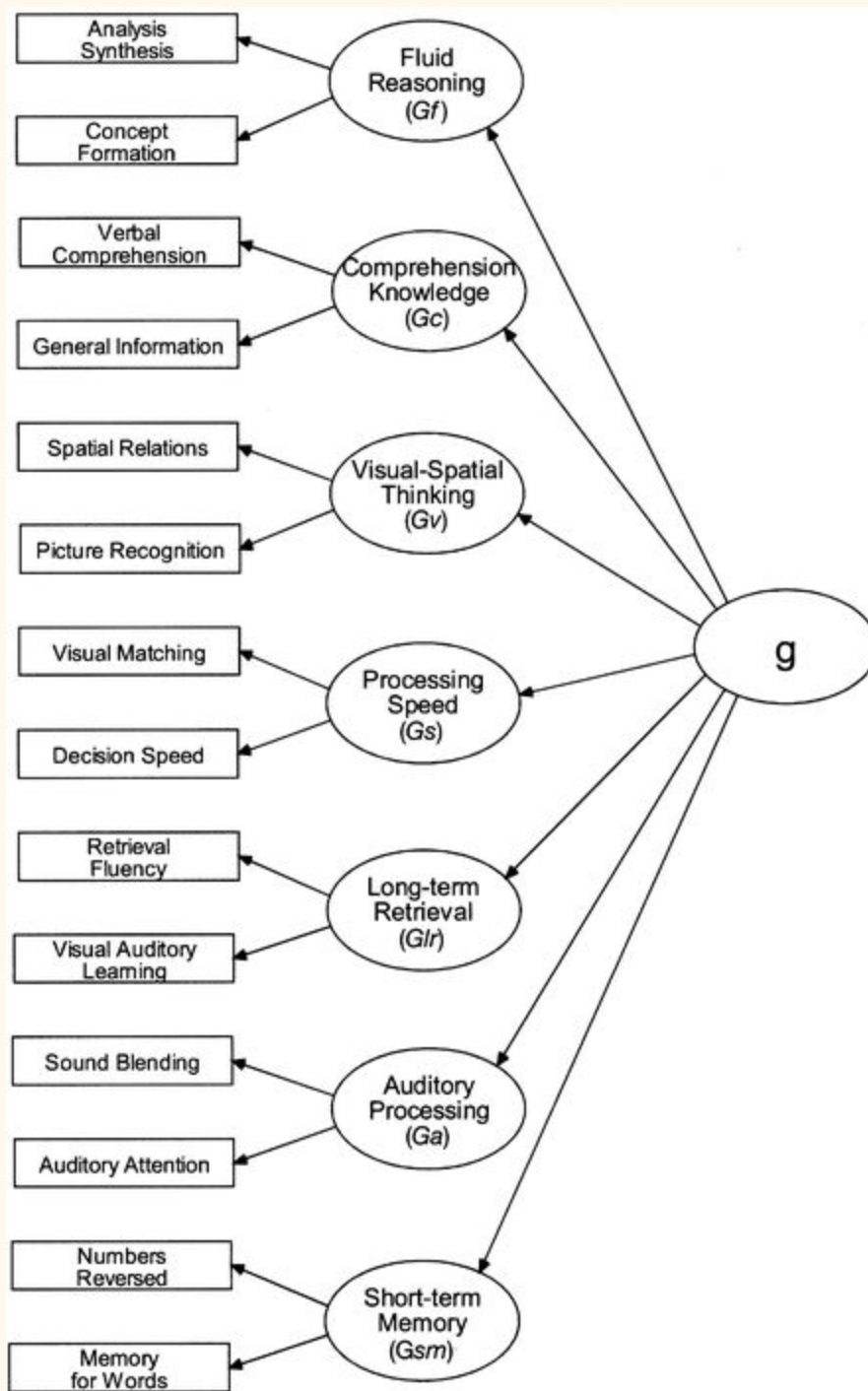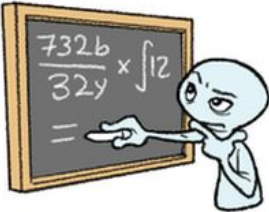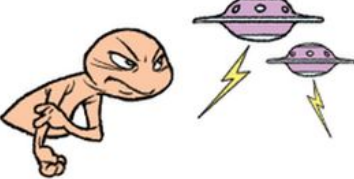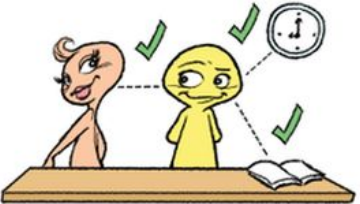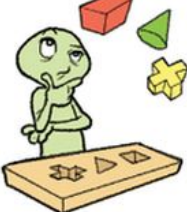
g, broad abilities, and their IQ subtests

So what *are* these broad cognitive abilities underlying our general intelligence?

All 9 are defined in this cartoon, taken from *Ungifted: Intelligence Redefined* by Scott Kaufman. Note that the label 'working memory (*Gwm*)' is now preferred to 'short-term memory' (*Gsm*) (ref).

Broad Abilities Assessed in IQ Tests

Typically **5-7** of the broad abilities are measured by **sub-tests** in full-scale IQ tests such as the WJ-IV. For instance, the Spatial Relations and Picture Recognition subtests of the WJ-IV are measures of Visuospatial Processing (G*v*) while the Concept Formation and Analysis-Synthesis subtests are measures of Fluid Reasoning (*Gf*).

The broad abilities of the CHC model often measured by subtests of full scale IQ tests are the following:

Comprehension Knowledge (*Gc*)

Also called 'Crystallized Intelligence'. This is knowledge and skills gained through experience, education and training. It depends on what we learn from our surrounding culture, and may be tested by vocabulary or general knowledge IQ subtests. Crystallized intelligence tends to remain constant over the lifespan and can even increase by acquiring more knowledge and skills.

> **Vocabulary-The examinee is asked to orally define words covering a wide range of difficulty. The test is designed to measure knowledge of words, which correlates with general mental ability.**
> 1. What does *retain* mean?
> 2. What does *robust* mean?
> 3. What does *sojourn* mean?
> 4. What does *harass* mean?
> 5. What does *desultory* mean?
> 6. What does *inclement* mean?

Gc IQ subtest questions

Fluid Reasoning (*Gf*)

Also called fluid intelligence, this is our on-the-spot reasoning and problem solving ability, not dependent on background knowledge, education or any specific expertise. It enables us to see relationships and learn quickly in new situations.

Fluid reasoning overlaps with other broad abilities as shown below (ref). *Gf* is the broad ability most closely associated with general intelligence (*g*).
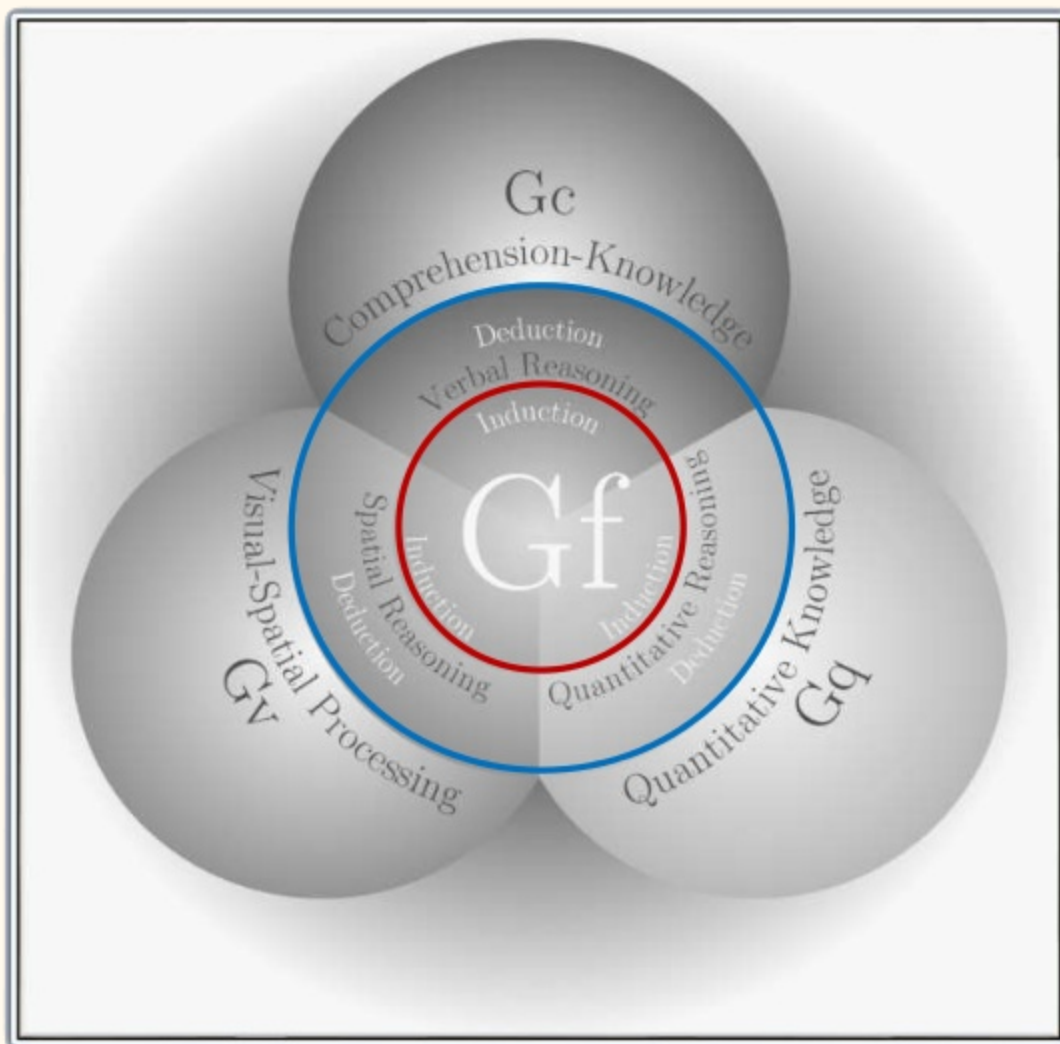
Inductive (e.g. matrices) and deductive reasoning (logic) tests give us measures of *Gf* in IQ. Concept formation and analogical reasoning tests can also be used as measures of *Gf*.

Similarities-Presents two words that represent common objects or concepts. The examinee is asked to state how the objects or concepts are similar. The task is designed to measure logical or abstract thinking and the ability to categorize and generalize.

In what way are a lion and a tiger alike?

In what way are a saw and a hammer alike?

In what way are an hour and a week alike?

In what way are a circle and a triangle alike?
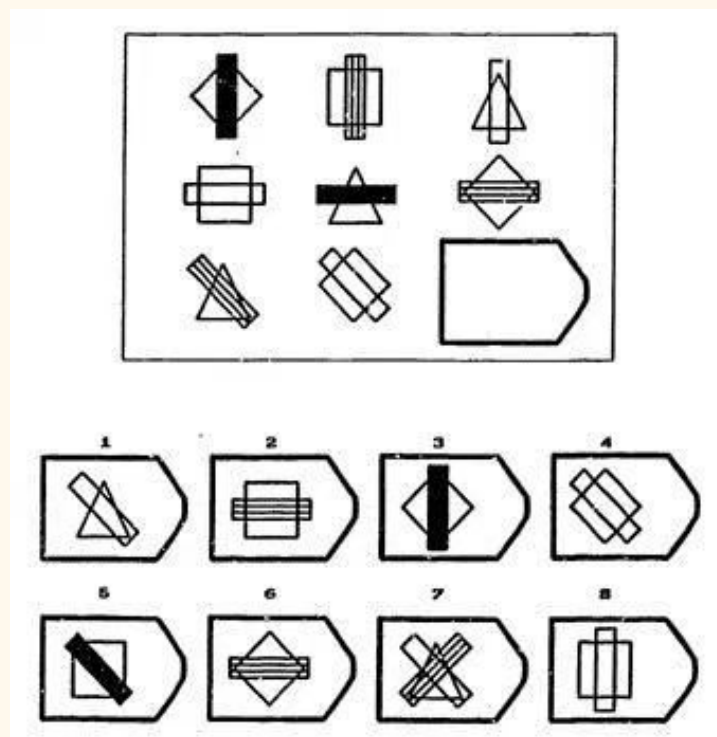
Gf IQ subtest question

Visuospatial processing (*Gv*)

Visual processing or visual-spatial intelligence (*Gv*) involves the ability to visualize, remember and manipulate images or shapes in the 'mind's eye'. This kind of intelligence is measured by tasks where you need to mentally simulate how complex patterns might look when transformed (visualisation) or remembering complex patterns over short periods of time (visual memory).
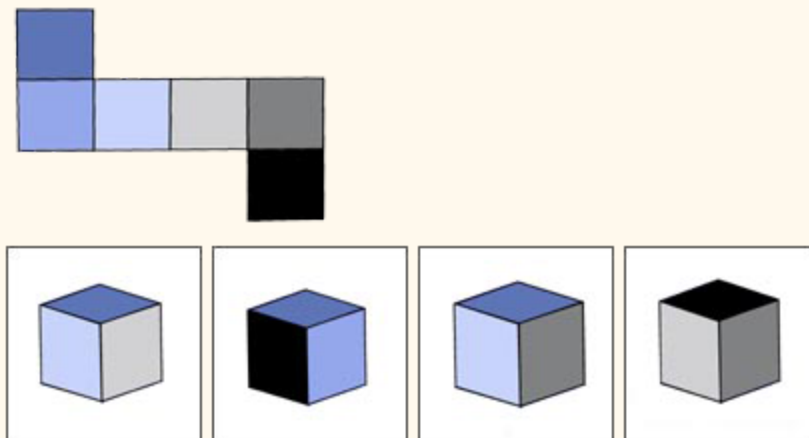
"Which 3 of these pieces go together to make this puzzle?"
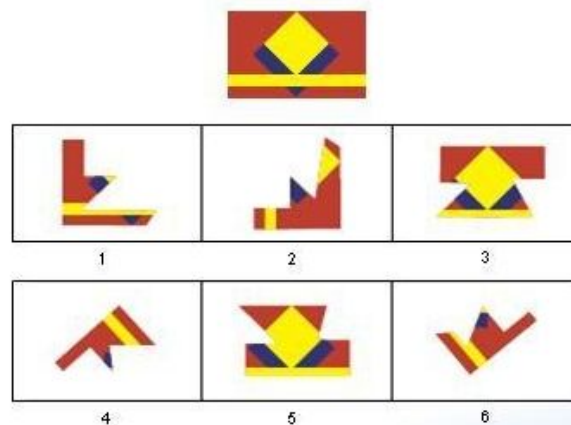
Gv IQ subtest questions

Processing speed (*Gs*)
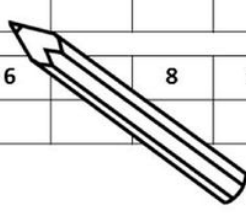
Processing speed (Gs) is attention-focused speediness – your ability to automatically and fluently perform basic cognitive tasks (such as scanning or key pressing) that do not require much thinking - but still require concentration. This is measured by IQ sub-tests such as digit symbol matching (see below).

Gv IQ subtest question

Working Memory (Gwm)

Also referred to in the CHC theory as Short Term Memory (*Gsm*). This is a **'mental workspace'** memory system that holds in current awareness information needed to problem solve, comprehend, reason, make decisions and so on. Unlike the unbounded long term memory, this is a **limited capacity** system that loses information quickly if it is not maintained in goal-directed cognition. It is measured by subtests such as memory span - both forwards and reversed.

designed to measure attention span and working memory, which holds information in storage temporarily.	
Digits forward	Correct response
3-9	3-9
4-2-6	4-2-6
7-1-8-7	7-1-8-7
5-8-2-3-9	5-8-2-3-9
Digits backward	Correct response
4-7	7-4
3-9-1	1-9-3
2-1-4-6	6-4-1-2
8-5-6-3-1	1-3-6-5-8

Gwm IQ subtest question

Quantitative Knowledge (*Gq*)

Quantitative knowledge (*Gq*) is mostly built up during formal educational experiences. Gq is a person's store of acquired mathematical knowledge and well practiced techniques for solving mathematical and quantitative problems. An example subtest for *Gq* is Figure-Weights.
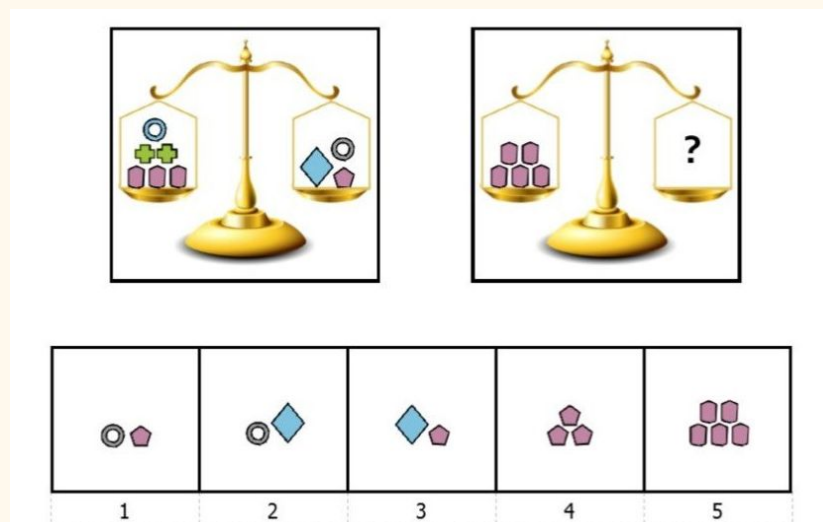
Gq IQ subtest question

The Cognitive Performance Model

The Cognitive Performance Model was developed by Richard Woodcock, one of the developers of the Woodcock Johnson IQ test (e.g. WJ-IV) (ref). It provides a more meaningful way of understanding the CHC theory of intelligence.

The broad abilities of intelligence are organized into three *information processing systems***:** (1) stores of **Acquired Knowledge**, (2) **Thinking Abilities**, and (3) **Cognitive Efficiency** (ref). An interaction of all three of these, as well as facilitators such as motivation level or inhibitors such as lack of sleep, determine cognitive performance (*g*).
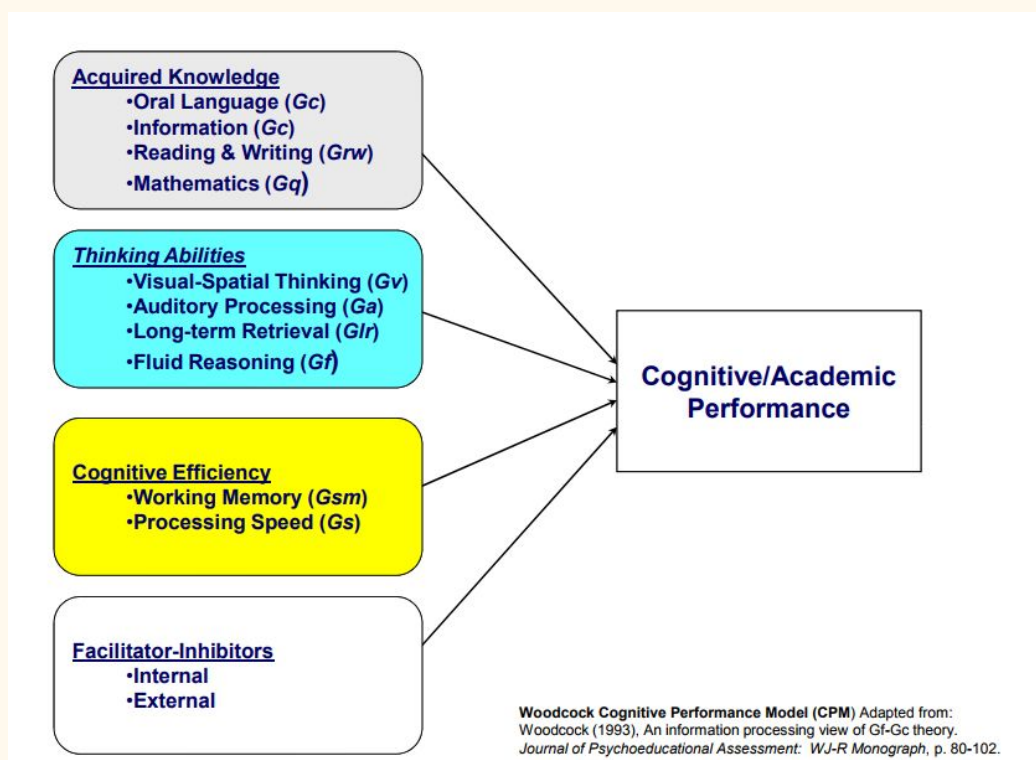
The Cognitive Performance Model

Acquired Knowledge (*Gc, Grw, Gq*)

This includes general knowledge, spoken language ability, math skills, reading and writing skills. The quality of learning and performance is dependent on the relevant

knowledge a person has. Knowledge is like scaffolding. Once information is learned, it can become a basis for new learning; missing information or knowledge can obviously impede future learning. Instruction strategies and opportunities for enrichment can affect a person's level of performance in this system.

All cognitive performance, whether automatic skills or new learning, is constrained by the store of knowledge that is available to you.

Thinking Abilities (*Gf, Gv, Ga, Glr*)

The thinking ability includes the ability to abstract ideas, to solve new problems, to process visual and auditory stimuli and to learn and to retrieve information from long term memory.

Cognitive Efficiency (*Gwm, Gs*)

The cognitive efficiency system includes the capacity of working memory (our mental workspace) as well as processing speed (our ability to perform a task quickly and with attentional focus). Expert performance is constrained by working memory and processing speed.

Facilitators-Inhibitors

Internal- e.g. health, emotional state, personality & motivation. F

External - e.g. external distractions, the unique IQ test taken, time constraints.
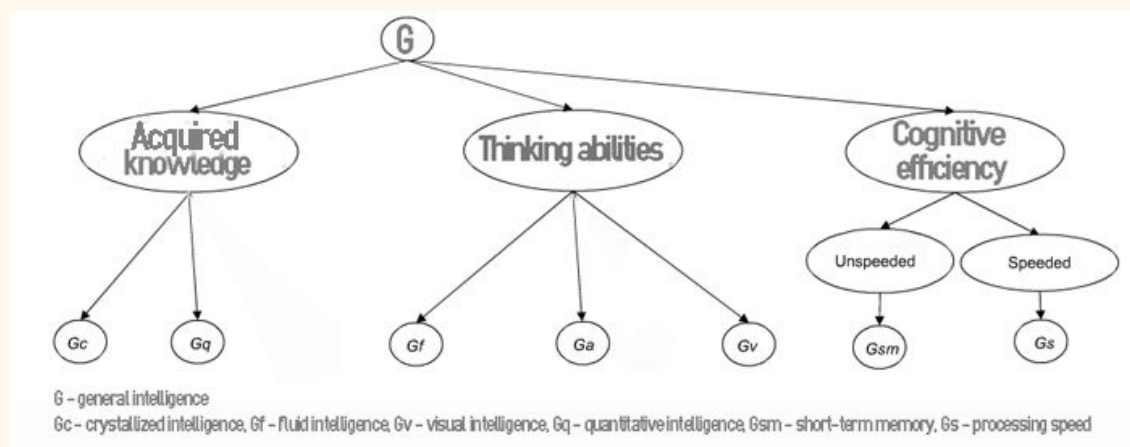
The Cognitive Performance Model with 7 Broad Abilities

The Cognitive Performance Model is the basis for the design of the scientific [i3 Mindware app](#) for IQ augmentation.

Summary

In this chapter I have attempted to *define* what it is that IQ tests measure. I have introduced some concepts from the field of psychometrics, and given an overview of the well-established CHC Theory of General Intelligence (*g*) with the nine broad cognitive abilities underlying *g*. We then looked more closely at the broad abilities of IQ typically assessed by IQ tests. I also gave an overview of the Cognitive Performance Model - a useful way of understanding the nature of intelligence. This interprets general intelligence measured by IQ tests as made up (i) acquired knowledge, (ii) thinking abilities, and (iii) cognitive efficiency.

2. 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 chapter'!

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.
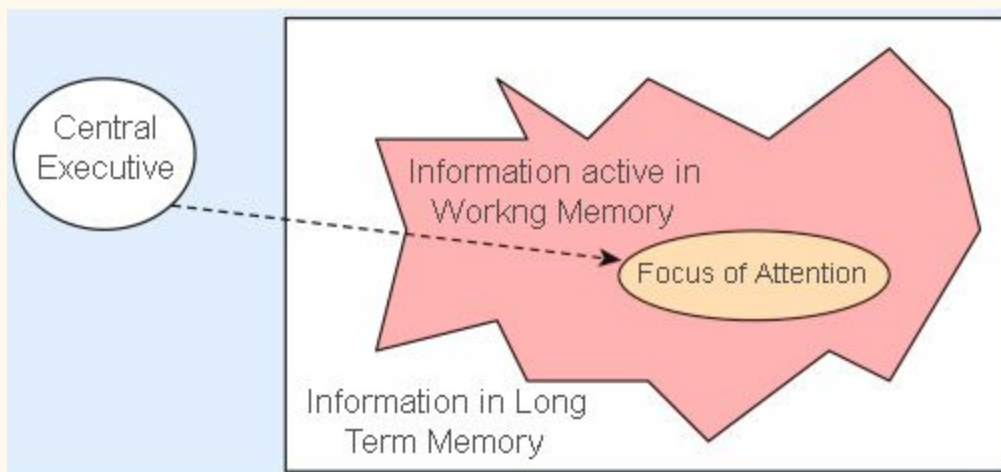
Cowan's model of working memory (1988) ([ref]())

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

Tying all the threads together discussed in the previous chapters, 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.
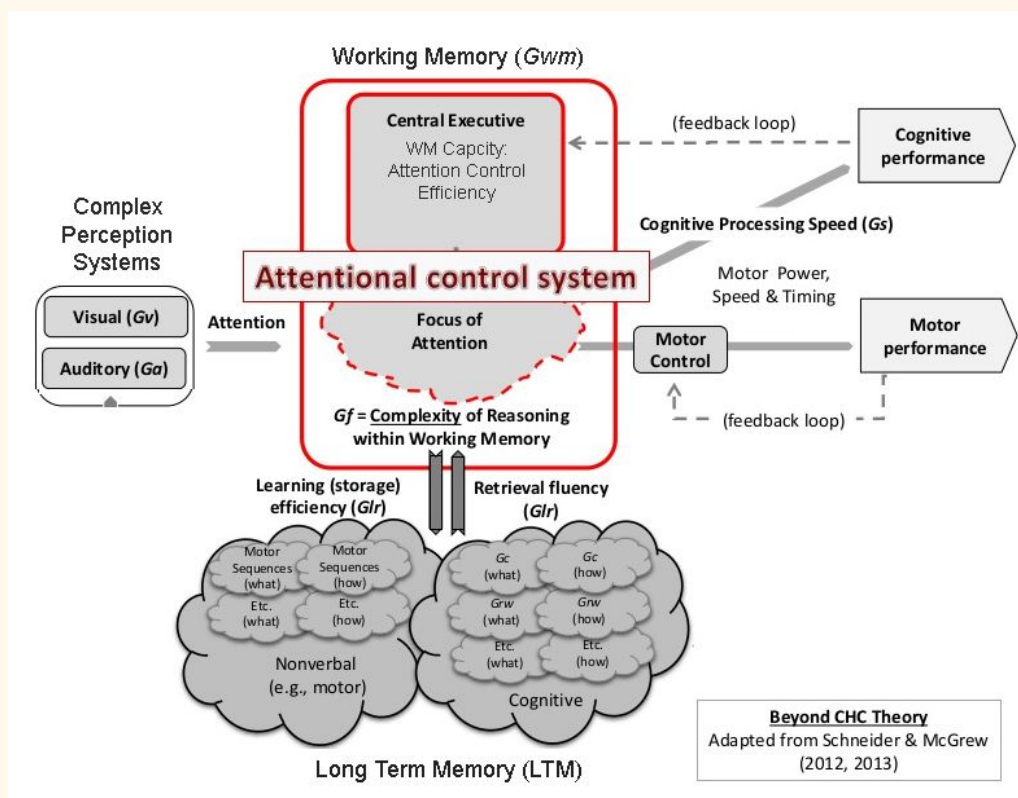
Schneider & McGrew's Attention Control Syste m Theory of Intelligence (2012/2013) (ref)

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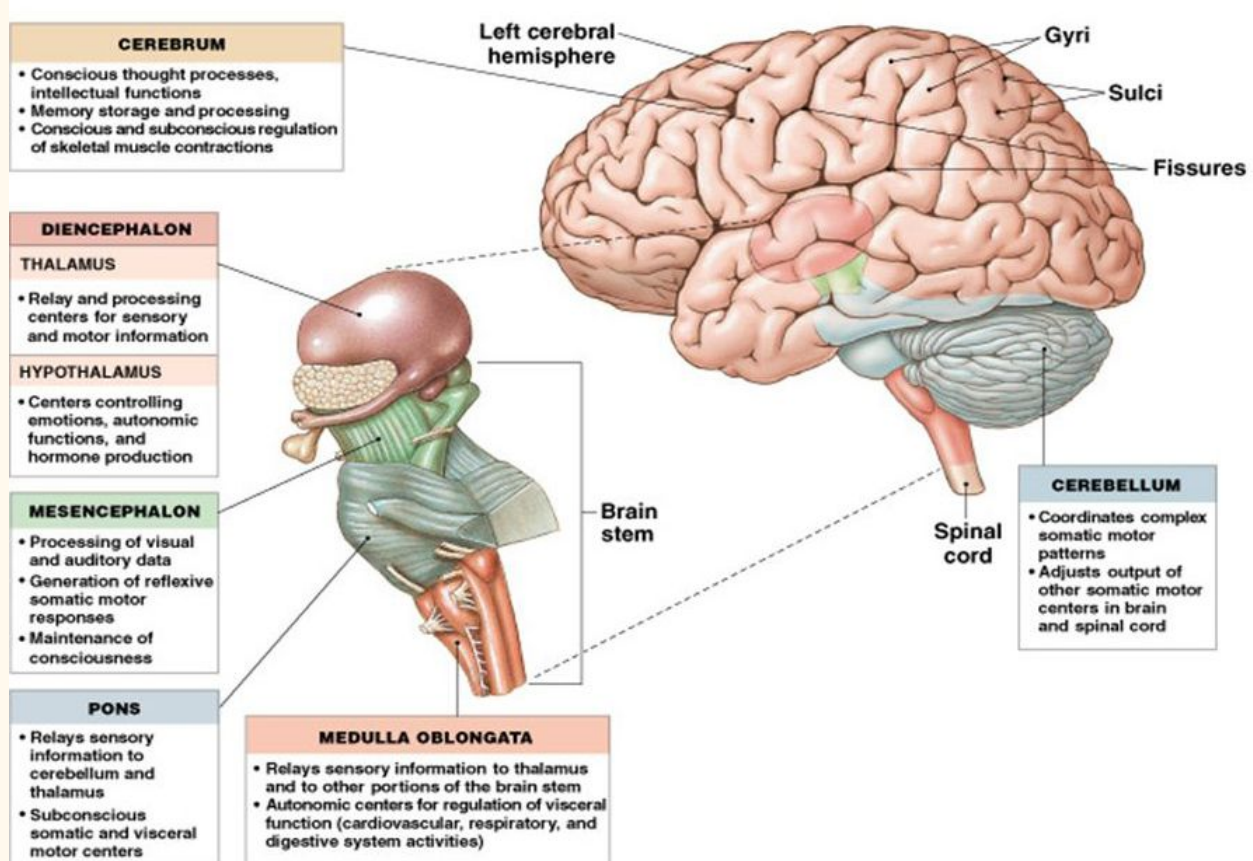
IQ tests measure cognitive abilities based in the **cerebrum** which contains the large **cerebral cortex** (both left and right hemispheres) as well as **subcortical** structures such as the hippocampus and basal ganglia.

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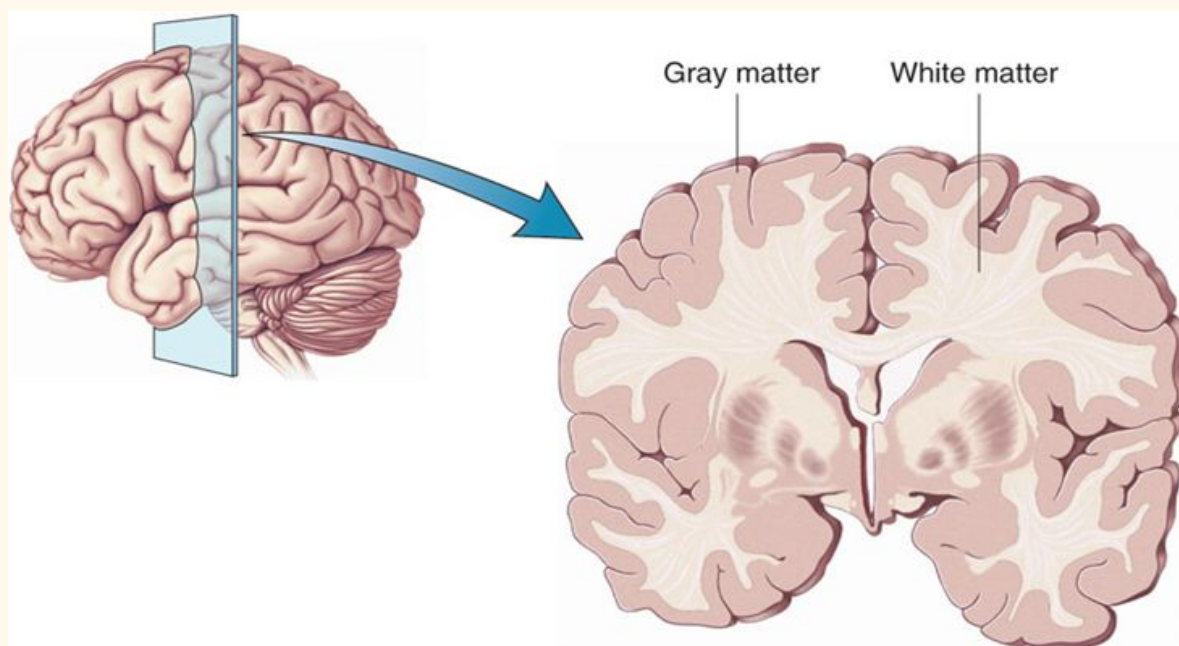
The human cerebral cortex contains approximately 15–33 billion neurons, each connected by synapses to several thousand other neurons.

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.
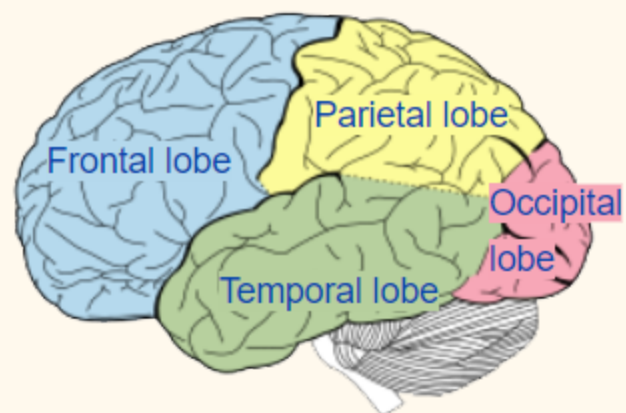
Different cortical lobes are the seat of different brain functions.

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.
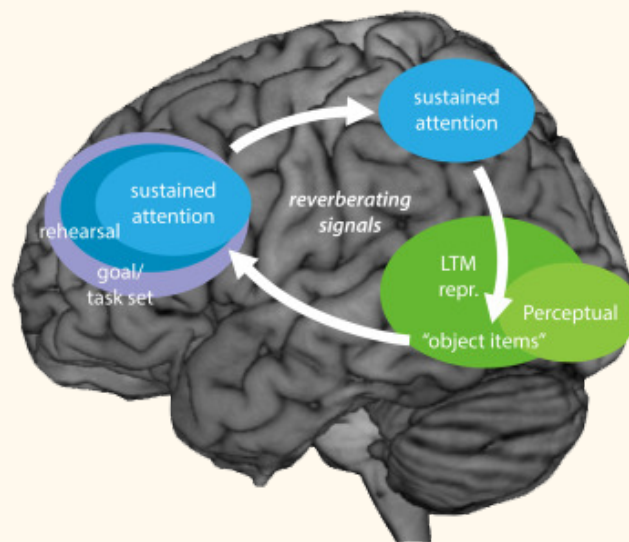
From Eriksson et al, 2015 ([ref](ref))

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](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.
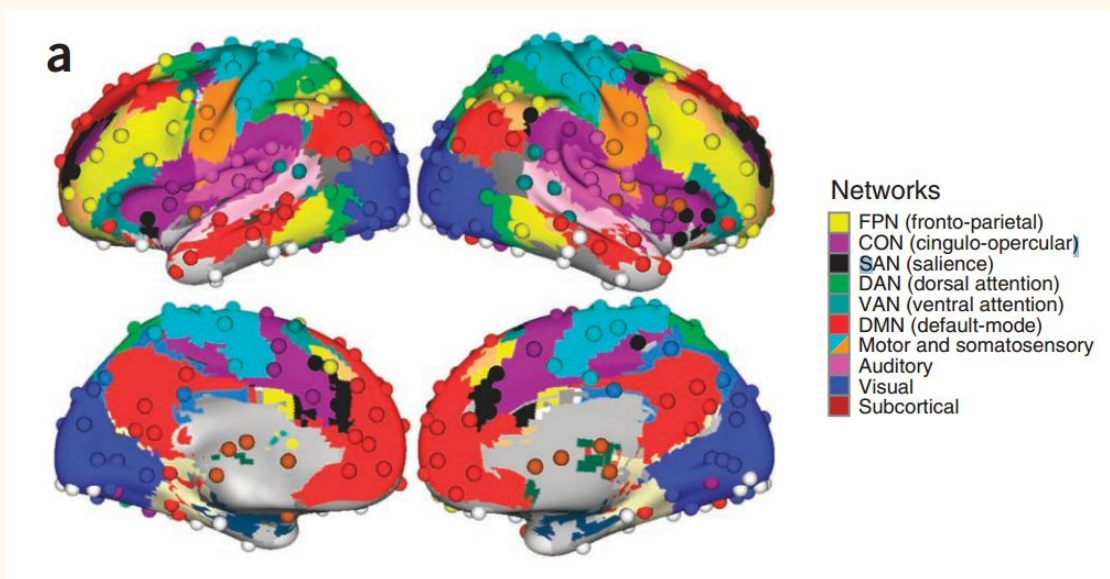
Functional Power et al., 2011

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.
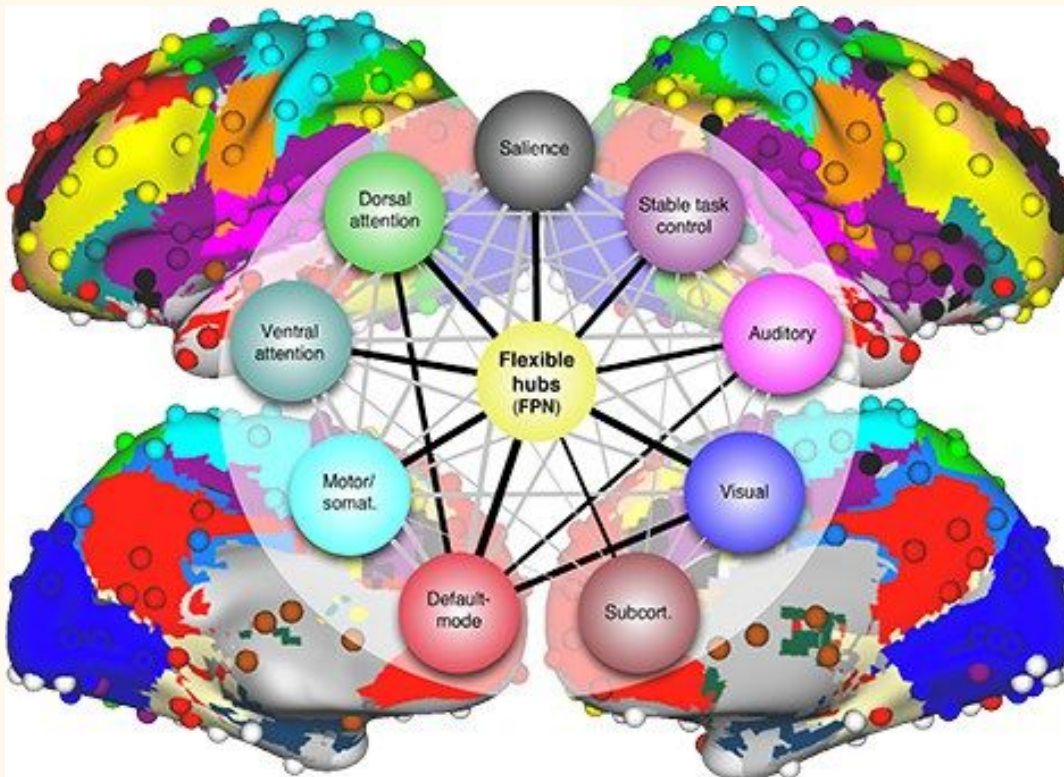
The Fronto-Parietal Network (FPN) Hub ([Ref](#))

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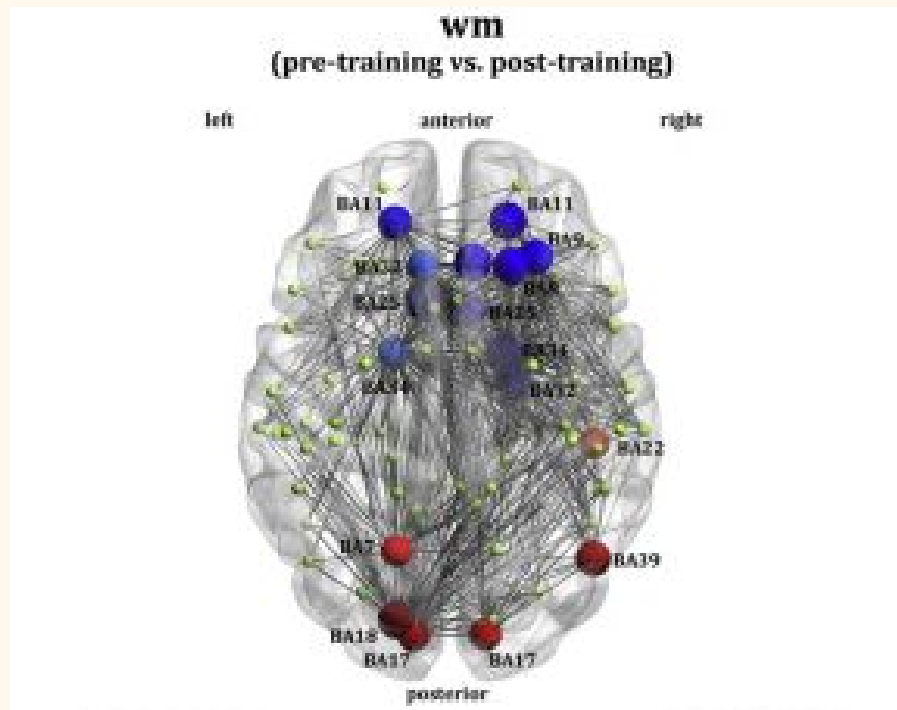
Pre-training vs post WM-training FPN network efficiency (ref)

Summary

In this chapter 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 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.

3. IQ TESTS

'IQ' stands for 'intelligence quotient'. Scientifically valid IQ Tests are standardized psychometric tests of general intelligence (*g*).

Scientifically valid means that they actually measure general intelligence rather than some other cognitive ability or abilities.

Standardized means that scores can be compared in the general population and you know what score is needed to be in a certain percentile – for instance above average or in the top 2% (Mensa standard).

> *There are many bogus IQ tests on the web that either don't accurately or reliably measure your general intelligence, or which give you an inflated score. Valid, standardized tests are difficult to locate and are usually professionally administered.*

IQ test scores can be used to predict achievements in a wide range of abilities, including creativity, educational attainment, health, leadership, lifespan, professional achievement and income.

IQ tests are widely used in our institutions and organisations because of their consistency and validity. Schools and universities use IQ tests (or 'aptitude tests') to select and stream students, companies use IQ tests to screen applicants, with estimates of 80% of Fortune 500 companies' HR departments using these kinds of psychometric tests for recruitment.

The IQ Score Bell Curve: A Normal Distribution

With standardized IQ tests, the tests are designed so that their scores have a 'bell curve' distribution in the general population with an **average of 100.**

The distribution curve has a peak in the middle where most people score and tapering ends where only a few people score. In statistics this is called a **normal distribution**. Many variables in nature (such as height and weight) have a distribution of the same shape.
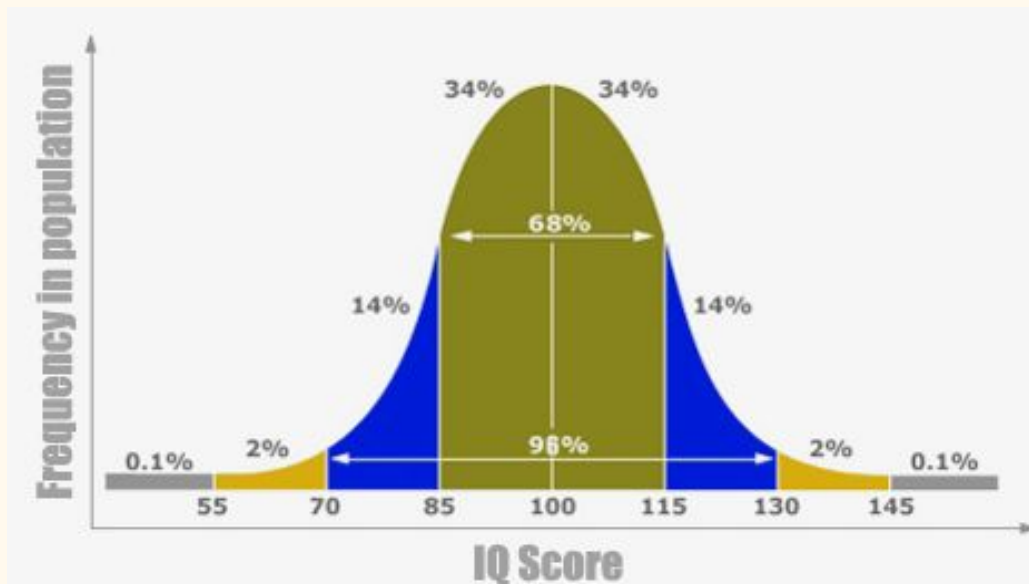
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IQ Bell Curve

The area under the curve between scores corresponds to the percentage of the population between those score. The scores on this IQ bell curve above are color-coded in *standard deviation units*. A standard deviation is a measure of the *spread* of the distribution. 15 points is one standard deviation for most IQ tests. Nearly 70% of the population score between 85 and 115 – i.e. plus and minus one standard deviation. A very small percentage of the population (about 0.1% or 1 in 1000) have scores less than 55 or greater than 145 – that is, more than three standard deviations from the average score.

A critical insight from research over the past decade is that IQ is not a fixed, genetically determined attribute. An individual's score on the bell curve is not static. Over time – weeks, months or years – an IQ level can change substantially.

What is an Average IQ Score?

Standardized IQ tests are designed so that the exact average (mean) IQ score in the general population is 100. An 'average IQ score' or 'normal IQ score' can be defined as a score between 85 and 115 – between plus and minus one standard deviation from the average (see the table below).

What is a High IQ Score? What is Mensa Standard?

An IQ of 115 or more can be considered to be a high IQ score or level. Only 15% of the population have an IQ level of 115 or above. There is no magic bullet but in general it is thought that:

- An IQ of **110** or above typically enables you to attain a college level education.
- If you have an IQ of **115** or above you are capable of the cognitive demands of almost any profession, and can attain the highest levels of education and training.
- The entry score for An IQ of **124** is needed to become a member of the [International High IQ Society.](#) This is the first entry-point score into high IQ societies. This is another criterion for a high IQ score.
- The average Harvard University undergraduate IQ in one study was **128.1**.
- Around 2% of the population (98th percentile and above) has an IQ greater than **130** which is 'gifted' intelligence. This is an IQ of 2 standard deviations from the average IQ. This is **Mensa standard** – the IQ score on a valid, standardized IQ test required to become a member of Mensa.

① Average IQ score
② High IQ. High performance. Top 15%
③ Gifted. Mensa level. Top 2%
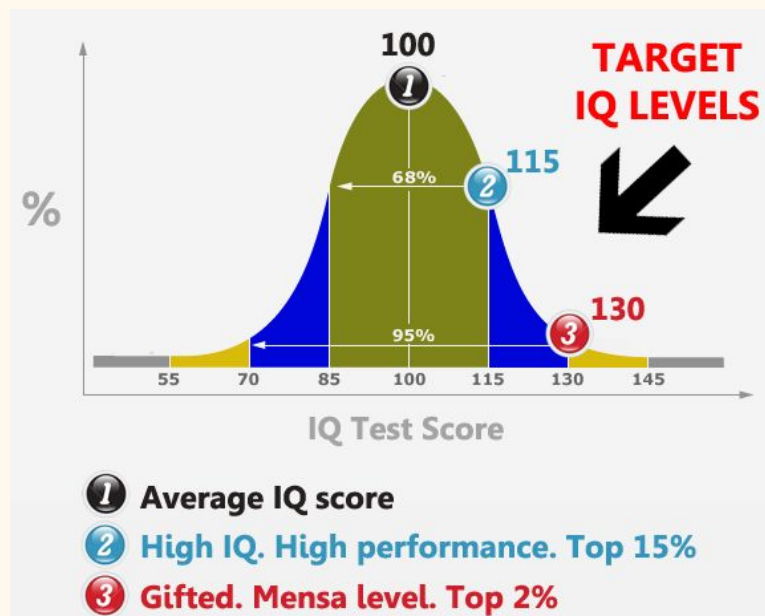
IQ Level Scale

This table indicates how IQ levels can be classified. The IQ ranges are conventional ones.

Classification	IQ Range	%
highly gifted	140+	0.4%
Mensa membership	130+	2%
gifted	130+	2%
International High IQ Society membership	124	5%
high	115-129	15%
high average	110-114	25%
average	90-109	50%
low average	85-89	23%
borderline	70-79	8%

Types of Intelligence Test

There are two broad types of intelligence test:

1. Full Scale IQ Tests

IQ tests giving a measure of overall intelligence (*g*), made up of a **test battery** of different **subtests** for 5-7 of the broad ability domains identified in the CHC theory of intelligence. Examples are the WJ IV, WAIS-IV, WISC-V and Cattell III B.

For an example, the WJ IV broad abilities and their subtests are:

Fluid reasoning (Gf): Concept Formation, Number Series, Analysis-Synthesis

C**omprehension-knowledge (*Gc*):** Oral Vocabulary

Working memory (*Gwm*): Verbal Attention, Numbers Reversed

Processing speed (*Gs*): Number-Pattern Matching, Pair Cancellation

Auditory processing (*Ga*): Phonological Processing

Long-term storage & retrieval (*Glr*): Story Recall

Visuospatial processing (*Gv*): Visualization

The well-known **WAIS-IV** full scale IQ test has its own broad ability classification system. Fluid reasoning (*Gf*) and Visuospatial processing (*Gv*) are grouped together under a 'Perceptual Organization Index'. Other broad abilities with subtests in the WAIS-IV are Working memory (*Gwm*), Comprehension-knowledge (*Gc*) , and Processing speed (*Gs*). The subtests for each Index are listed at the bottom of the figure.
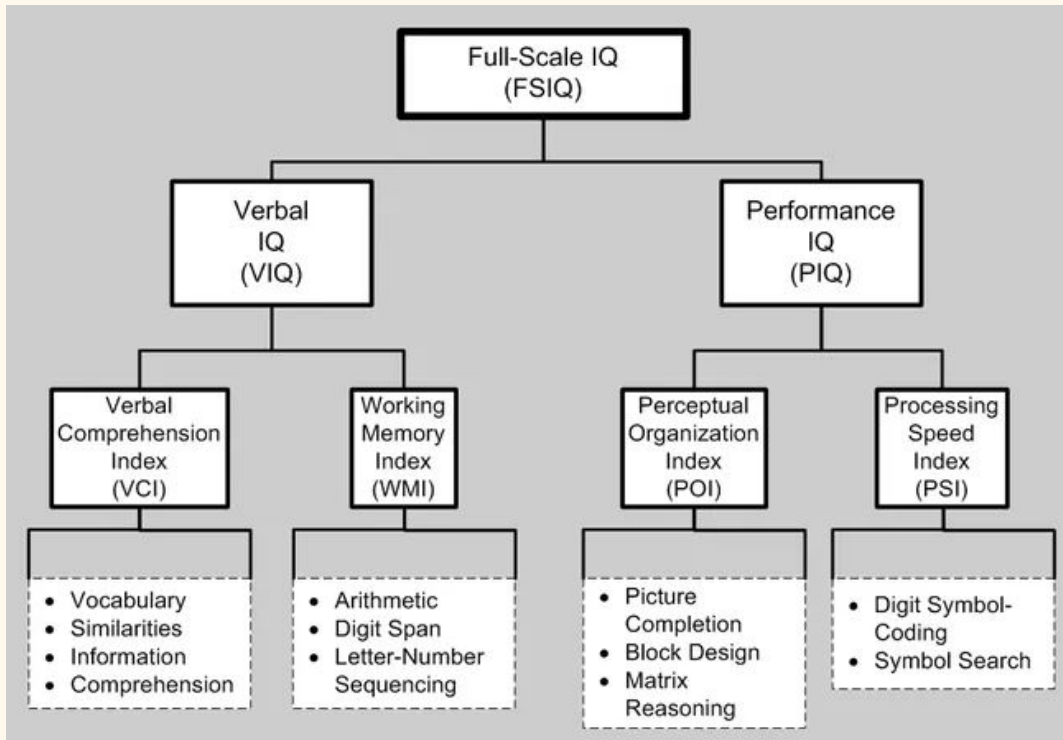
WAIS-IV taxonomy

2. Culture-Fair IQ Tests

IQ tests of cognitive ability that are designed to be independent of language and cultural background. One of the broad abilities tested in well-known full-scale IQ tests such as the WAIS-IV or WJ-IV is Comprehension-knowledge (*Gc*) - with subtests such vocabulary and general knowledge. Scoring well on a *Gc* subtest clearly depends on language and cultural background. This puts individuals who have not grown up in an American culture with English as a first language at a disadvantage. Culture fair tests are designed to get around this problem, focusing on broad abilities such as Fluid reasoning (*Gf*) and Visuospatial processing (*Gv*).

Examples of culture fair IQ tests are the Raven's Advanced Progressive Matrices, and Cattell Culture Fair III A.

Raven's Advanced Progressive Matrices (APM) IQ Test

The APM (ref) is a popular career / job aptitude test. It primarily measures the Fluid reasoning (*Gf*) broad ability -   our on-the-spot reasoning and problem solving ability, not dependent on background knowledge, education or any specific expertise.

As described by the publishers of the Raven's Advanced Progressive Matrices test:

"The APM score can be used as an indication of a candidate's potential for success in high-level technical, professional, and executive positions that require high levels of clear and accurate thinking, problem identification, holistic situation assessment, and monitoring of tentative solutions for consistency with all available information. The APM score also can be used for developmental purposes in occupational and advanced educational settings. The nonverbal aspect of the test minimizes the impact of cultural or language bias."

Different countries have different average scores on this test (ref).

Country	N	Mean
Australia/New Zealand	128	11.95
France	106	14.33
India	100	9.51
Netherlands	103	13.01
UK	101	12.38
US	175	12.23

Here is an example of a progressive matrix problem of the sort found in the APM test. You need to choose from 1-4 to fill in the missing matrix. Notice that in each row, the 3rd matrix is the addition of the first two.

Matrix reasoning IQ problem

IQ Test Ceilings

What is the highest you can score on a professionally proctored IQ test?

The answer is typically anywhere from 160 to 170. Here is a table showing the max scores on some of well-known full scale IQ tests.

Intelligence Test	Test Ceiling

Wechsler tests
    WPPSI-R (ages 3-7)
    WISC-III (ages 6-17)
    WAIS (ages 16 +)
	160 full scale
	    standard deviation (s.d.) 15

Wechsler tests
    WPPSI-III (ages 3-7)
    WISC-IV (ages 6-17)
	160 full scale
	    standard deviation 15
	
	210 extended scale, with subtest ceilings of up to 28
	(Harcourt Assessment WISC-IV Technical Report #7
	WISC–IV Extended Norms)

Stanford Binet, Fourth Edition	164 standard deviation 16
Stanford Binet 5	160 standard deviation 15
Differential Abilities Scales (DAS)	175 (lower at ages approaching 17) standard deviation 15

For highly gifted individuals who reach the ceiling in their scores, there are **extended IQ scales** which give scores up to 210 (WISC-IV Extended Scale) & 225 (SB5 Extended Scores) (ref).

Highest IQs in the World

There are a number of individuals with IQs estimated to be >200. Here are two well-known examples:

Terence Tao, an Australian mathematician of Chinese origin. He was capable of performing basic arithmetic by age 2. Tao earned his PhD from Princeton by age 20 and is now a full time professor at UCLA.

Christopher Hirata - an American child prodigy who had won a gold medal at the Physics Olympiad by age 13, earning his PhD from Princeton by 22. He has worked on a project exploring the possibility of colonizing Mars for NASA (ref), and currently works at the Center for Cosmology and Astroparticle Physics at the Ohio State University. His app innovations can be found here.

IQ Test Score Variation

Would you expect to get the exact same score if you took one scientifically valid, standardized IQ test, and then another one? The short answer is no. Correlations reported between major IQ tests usually range from the .60s to .80s, with the highest correlations typically found in the .70 to .80 range (ref).

> *Correlation: An index measuring the degree of relationship (usually linear) between two attributes scaled so that the value of +1 indicates a perfect positive relationship, -1 a perfect negative relationship, and 0 no relationship.*

In one study looking at test scores of the 55 individuals for two different full-scale IQ tests - the WAIS-R and the WJ-R it is clear that there is surprising range scores (ref). In this sample 2 individuals actually scored 20 points more on the WAIS-R than the WJ-R.
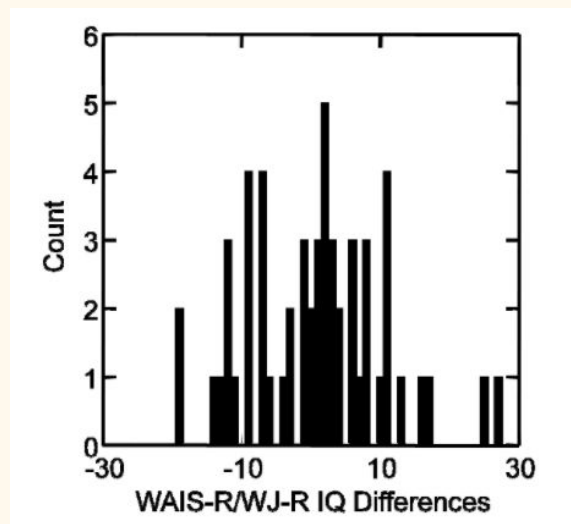
Another study ([ref](#)) looking at a variety of contemporary full scale IQ tests (also called 'test batteries') has concluded that:

> *"Psychologists can anticipate that 1 in 4 individuals taking an intelligence test battery will receive an IQ more than 10 points higher or lower when taking another battery."*

The differences are in part due to measurement error (which may be the result of different conditions while taking the test), but also significantly due to *non-shared cognitive abilities* actually measured by different IQ tests. Some full scale IQ tests may measure broad ability domains such as Auditory processing (Ga) not measured in other IQ tests. And a single broad ability such as Working memory *Gwm* is a highly complex cognitive ability, and two IQ tests may measure non-overlapping components of the brain's Working memory ability.

The take-home from these multiple IQ test studies is that a given full-scale IQ test score you may obtain should reasonably be interpreted as a score within 10 points of another full-scale IQ test you may take. Identical scores on two independent tests is unlikely.

How To Test Your IQ?

Most IQ tests on the internet are not standardized tests. If you want to test your own IQ level, how do you go about it?

One approach is to take a professional IQ test administered by a qualified test-administrator, such as a private psychologist or a Mensa test official.

Professionally administered IQ tests

Professionally administered IQ tests (e.g. WAIS-IV or Cattell III B) give you an accurate measure of your IQ level. They are typically administered by a certified psychologist, educationalist or clinician. They cost to you will be in the region of $300-$500 for an assessment. The test kits can be purchased independently – at a high cost: up to $1,110.00 for the WAIS-IV test battery ([link](#)).

Mensa Admission Test

A cost-effective method of measuring your true IQ level is to take the supervised Mensa Admission Test. Mensa offers supervised IQ tests - and tests can be taken in most countries. The test-taking fee varies from country to country - for instance in the US the fee is now $60.00 (ref); in the UK the fee is now £24.95 (ref). You will need to check for details in your home country's Mensa website. This fee will buy you:

- A reserved place at the centre of your choice.
- The marking of your IQ test papers and your results returned to you in confidence.

Mensa test sessions are held at centres throughout your home country. Details can be found at one of these links:

- **International Mensa**
- **US Mensa**
- **British Mensa**

A follow-up chapter looks at preparing for the Mensa Admission Test to optimize your IQ score.

Free Online IQ Tests With Instant Results

There are many so-called 'IQ tests' online. The vast majority these are not scientifically valid or standardized. They may be fun, they may even be good for training purposes, but they are worthless as a measure of your general intelligence (*g*) level. The following tests should give you valid measures of your IQ measured by the broad Fluid reasoning (*Gf*) ability which has a high correlation with general intelligence (*g*).

Free Online Culture-Fair IQ Tests

Anders Jensen's IQ Test

This non-verbal IQ test is based on the well known Raven's Progressive Matrices. The IQ test is culture fair – eliminating the effect of cultural factors such as vocabulary and general knowledge. The calculation of IQ is based on answers from more than 250,000 people. The test is based on seeing relationships in abstract geometrical shapes. It is a measure of Fluid reasoning, which correlates highly with general intelligence (*g*).

Time required: 40 minutes time limit
Broad ability domain: Fluid reasoning (*Gf*)
Repeat testing? No
Fee: No charge
Instruction languages: English, Spanish, Danish, German
Creator: Anders Jensen, Mensa Denmark

The JCTI (Test of Induction)

This non-verbal IQ test of fluid intelligence (*Gf*) assesses your IQ through culture fair nonverbal matrices questions.

The JCTI correlates very highly with the IQ on traditional intelligence tests such as the Wechsler Adult Intelligence Scale III (WAIS-III) Full Scale IQ or the Slosson Intelligence Test – Revised (SIT-R3) Total Standard Score.

The JCTI has very high correlations with both the Scholastic Aptitude Test I (SAT I) combined score, and the SAT I Mathematical reasoning test scaled score. In the US you can use this test to predict your SAT performance.

Time required: No time limit – 52 item test
Broad ability domain: Fluid reasoning (*Gf*)
Repeat testing? No

Age: 15+
Age normed? Yes
Fee: No charge
Creator: Xavier Jouve, The Cerebrals Society
Special information: For information on how to interpret this test, click here.

IQ Brain IQ Matrices Tests

IQ-Brain.com offers 4 culture-fair IQ tests based on Cattell, Raven's Advanced Progressive Matrices and the Mensa-administered Figure Reasoning Test (FRT).

The IQ score estimates are comparable what users have been able to achieve on proctor-administered tests. The tests have a similar number of questions and time pressure as both FRT and the Cattell culture fair IIIa tests which are often administered by Mensa.

The test-developer recruited a cohort of test takers from all walks of life, but more importantly test takers who had taken a Mensa-administered IQ test. The test is calibrated to ensure that the raw score required to achieve a passing score of 132 was in line with the score needed to become a Mensa member. If you can achieve an IQ score of 132 on his tests, that you stand a good chance of achieving a similar result with a Mensa-administered test.

There is a free IQ test which provides you with a realistic assessment of your IQ standing, as per the following IQ categorisations:

> **Superior**: 120-129+
> **High average**: 110-119
> **Average**: 90-109
> **Low average**: 80-89
> **Very low average**: >80

Once you have taken our free IQ test, you may decide to take one or more of the full IQ tests online which will provide you a precise estimate of your fluid reasoning (*Gf*) IQ. The cost of 1 test result at last check is $9.00, 2 test results for $12.00 and 3 test results for $15.00. The tests measure IQs up to 148.

Take The Test

Online Full Scale IQ Tests

GIQ IQ Test

This full-scale IQ test will give you a valid estimate of your general intelligence (*g*). It is biased towards English language speakers. It has subtests for the following:

- Picture Questions
- Vocabulary Questions
- Recall Questions
- Relationship Questions
- Arithmetic Questions

The GIQ test does not have segregated subtests for the broad ability domains identified by the CHC theory (Chapter 1), but it will give you a valid and standardized estimate of your full scale IQ.

The fee is $10.

Take The Test

IQ Level Is Not Fixed: Intelligence Augmentation

Individual Differences in IQ: How To Use Your Scores

"Each mind has its own method." Emerson

"Minds differ more than faces." Voltaire

As already noted in the previous chapter, a major purpose of psychological testing is **selection** and **streaming** - for example testing for college admissions, job selection or admission to Mensa.

But as argued by the Director of the Institute for Applied Psychometrics, [Kevin McGrew](), a major purpose of psychometric testing: to appreciate *the individual difference terrain or landscape of each individual's personal abilities*. In other words, to understand each person's **unique personal profile** - their cognitive peaks (potentialis, capacities, strengths) and valleys (weaknesses, deficiencies), to design programs to allow them to reach their fullest potential.

This is the primary aim underlying the development of IQ increasing apps such as [i3 Mindware]() which provides its own scientifically valid IQ tests.

You can take a 'baseline' IQ test to estimate your current IQ level, and then re-test yourself after an IQ augmentation program. You should expect to see substantial increases in your IQ score, not just from practice on aspects of IQ such as Comprehension-knowledge (*Gc*) that benefit from learning, but also in terms of cognitive efficiency and 'processing power' - measured by e.g. Working memory (*Gwm*) or Processing speed (*Gs*).

IQ Augmentation Through Training

But it has become clear from peer-reviewed research in cognitive psychology as well as neuroimaging that some types of brain training are effective for inducing long-term neuroplasticity change and increasing general intelligence (*g*) as well as, IQ scores (reviews).

For instance working memory brain training such as i3 Mindware increases IQ in both working memory (*Gwm*) and fluid reasoning (*Gf*) – as well as improving attention control. The latest 2017 'meta-analysis' of all 33 published, randomized, controlled DNB trials from independent labs all around the world (ref) concludes there are real training effects of working memory brain training on IQ, beyond placebo effects and just getting good at the n-back game itself through practice. By comparison, the training effect on *Gwm* is as powerful as an effective antidepressant drug - an industry worth billions of dollars.
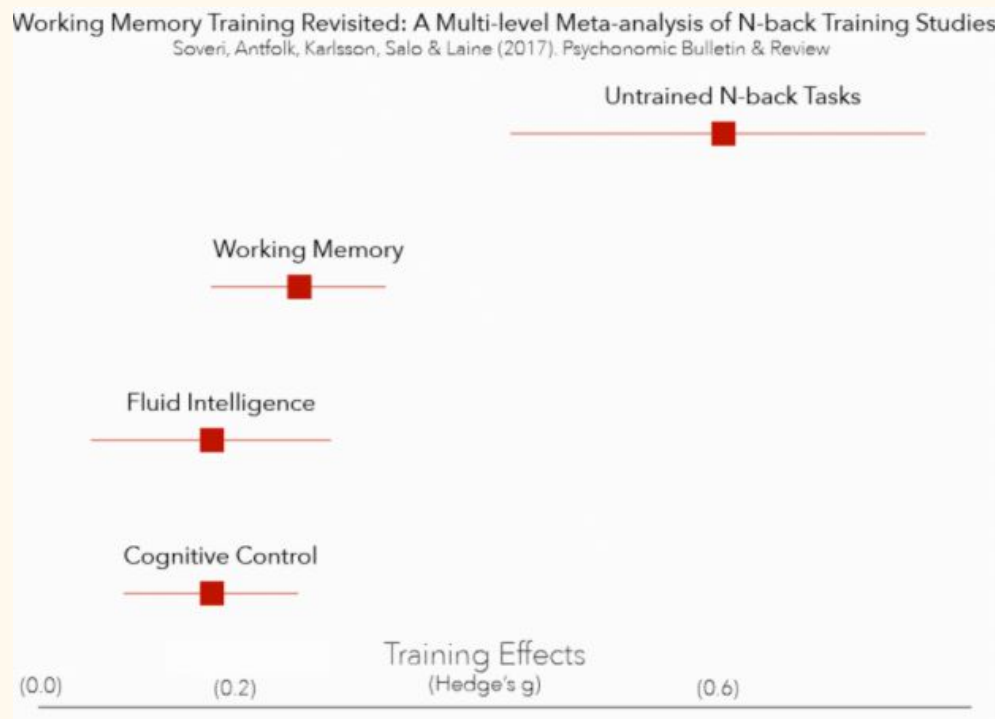
Training effect estimates of working memory brain training

Summary

In summary, we have explained what valid, standardized IQ tests and scores mean in terms of the IQ Bell Curve. We now know what an average and a superior IQ score is - including a Mensa qualifying score. We know there are two basic types of IQ test: full scale and culture-fair, and we have looked at some specific tests in both categories. We have also determined that there can be differences in test score results from one (valid) test to another. In general culture-fair matrices-type IQ tests that measure fluid reasoning (Gf) can be taken as a good estimate of full-scale IQ due to the high correlation between Gf and general intelligence (g), but an individual may have a strength in broad abilities not measured by matrices tests, and this should be taken into account when interpreting your own culture-fair IQ test scores. In this chapter we have also provided links to free online IQ tests that can be considered valid and standardized. We concluded by providing some data demonstrating that some types of brain training apps (such as i3 Mindware) can augment IQ scores. Intelligence level and IQ scores are not fixed, but can benefit from training programs.

4. HOW TO JOIN MENSA

The IQ Score Bell Curve: A Normal Distribution

As we saw in *Psychometric IQ Augmentation 2* with standardized IQ tests are designed so that their scores have a 'bell curve' distribution in the general population with an **average of 100.**

The distribution curve has a peak in the middle where most people score and tapering ends where only a few people score. In statistics this is called a **normal distribution**.
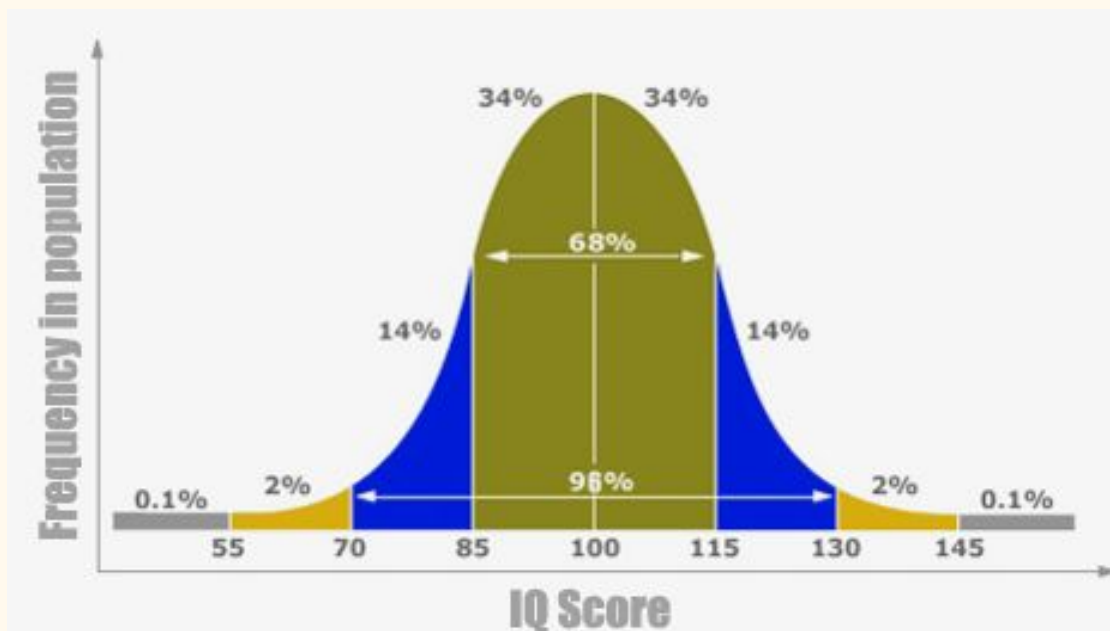
IQ Bell Curve

The area under the curve between scores corresponds to the percentage of the population between those score. The scores on this IQ bell curve above are color-coded in *standard deviation units*. A standard deviation is a measure of the *spread* of the distribution. 15 points is one standard deviation for most IQ tests.

An 'average IQ score' or 'normal IQ score' can be defined as a score between 85 and 115. 68% of people score between 85 and 115.

What is Mensa Standard?

Around 2% of the population (98th percentile or greater) has an IQ greater than 130. This is an IQ of 2 standard deviations from the average IQ. This is Mensa standard – the IQ score required to become a member of Mensa on a scientifically valid supervised IQ test.
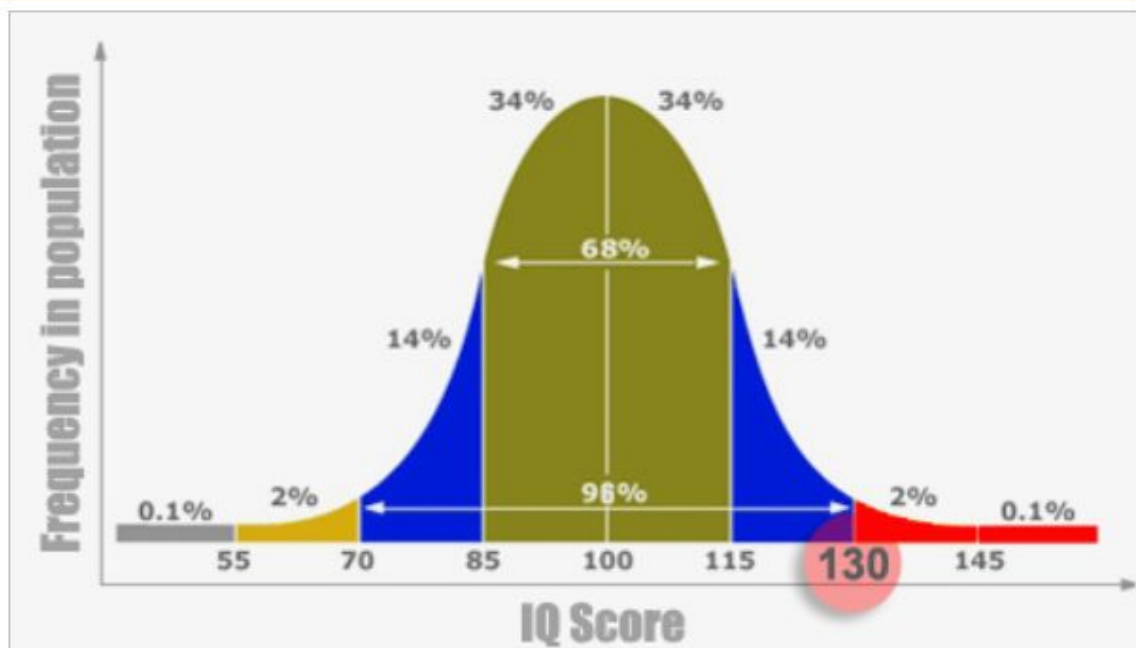
How To Test for Mensa?

Most IQ tests on the internet are not scientifically valid, standardized tests. If you want to test your own IQ level in a way that is accredited for Mensa, how can you go about it?

One approach is to take a professional IQ test administered by a Mensa test official (proctor).

Mensa Admission Test

A cost-effective method of measuring your true IQ level is to take the supervised Mensa Admission Test. The test-taking fee varies from country to country - for instance in the US the fee is now $60.00 (ref); in the UK the fee is now £24.95 (ref). You will need to check for details in your home country's Mensa website.

Mensa test sessions are held at centres throughout your home country. Details can be found at one of these links:

- **International Mensa**
- **US Mensa**
- **British Mensa**

In the US, proctors welcome you to schedule a supervised testing session in your area. Our Local Groups host test sessions throughout the year. You can enter your ZIP code here, to search for test sessions in your area.

American Mensa Supervised IQ Tests

American Mensa offers two IQ tests that can qualify you for membership: the standard full-scale standard IQ test battery or a culture-fair IQ test battery. The culture fair test battery is primarily given to those who do not speak English as their primary language or who have language-processing deficits such as dyslexia. Individuals who do not qualify via American Mensa's standard test battery can also take the culture fair battery as a means to qualify for membership. *The culture fair test is given on an 'as needed' basis, and you need to request this option specifically when scheduling a test session.* After taking the standard test, you can take the Culture Fair and vice versa.

The standard Mensa Admission Test battery takes **two hours** to complete. The culture-fair test takes **two to three hours** to complete. These are long test sessions!

Standard IQ Test Battery: This includes **two** IQ tests: the *Reynolds Adaptable Intelligence Test* (ref) and the Mensa version of the *Wonderlic* (ref). These tests have 'broad ability' subtests for Fluid reasoning (*Gf*), Comprehension-knowledge (*Gc*) and Quantitative knowledge (*Gq*). (These subfactors of IQ are defined with examples in *Psychometric IQ Augmentation 1.*) Test question examples are given below. If you score in the 98th percentile or above in **either** of these two tests, you will qualify for Mensa membership.

Culture-Fair IQ Test Battery: This includes the Cattell Culture Fair (ref), the Nonverbal Reasoning Test (ref) and the SRA Pictorial Reasoning Test (ref). Test items in these three tests are non-verbal visual puzzles - e.g. mazes, copying symbols, identifying similar drawings, picking a drawing that is different from other drawings, as well as matrix problems (similar to Raven's matrices tests) involving completing a

matrix of patterns. Test question examples are given below.   If you score in the 98th percentile or above in **any** of these three tests, you will qualify for Mensa membership.

Within seven to 10 business days, your tests are scored and a letter with your Mensa qualification status is mailed to you. This letter also contains the raw scores for each of the tests you take. As mentioned above, **you need qualify on only one of the tests to be offered membership**.

British Mensa Supervised IQ Tests

Supervised Mensa Admissions tests in the UK can be booked online at this link. You can take both the standard full-scale and culture fair IQ tests. A score in either test that puts you in the 98th percentile or higher qualifies you for Mensa membership. These tests are timed, so you will need to be careful with time management - ensuring you do not get fixated on early questions if you cannot initially solve them.

Standard IQ Test: This is the Cattell III B with 150 questions. This is a full-scale test, similar to the 'standard' test for American Mensa. You must be very fluent in English to score well on this test.

Culture Fair IQ Test: This is the Cattell Culture Fair III A, is largely diagrammatical, with 50 questions. This is similar to the culture-fair test for American Mensa.

It may take up to one month to get your test results for these tests.

Alternative Mensa Accredited IQ Tests

American Mensa accepts scores from approximately 200 different standardized intelligence tests. Standardized IQ tests accepted for Mensa membership are administered by school districts (e.g. the Cognitive Abilities Test (CogAT)), private psychologists, the military (e.g. Army GCT) and human resource departments (e.g. the Wonderlic). Sometimes potential members have taken on of these Mensa accredited tests at other times in their lives and don't realize they may already qualify for membership.

American Mensa provides some qualifying scores in the tables below, and details on how to submit scores are found here. For the UK, the relevant link is here. In other cases, you will need to check on your home country's Mensa website.

Tests commonly administered by school districts

Test Name	Qualifying Score
Cognitive Abilities Test (CogAT)	Composite SAS of 132
Differential Ability Scales (DAS)	GCA 132
Differential Ability Scales - Second Edition (DAS-II)	GCA 130
Naglieri Nonverbal Ability Test (NNAT)	Nonverbal Ability Index Score of 130 or above
Naglieri Nonverbal Ability Test 2 & 3 (NNAT2/NNAT3)	Nonverbal Ability Index Score of 132 or above
Otis Lennon School Abilities Test (OLSAT)	Total SAI 132
Otis-Gamma Test	IQ 131
Stanford Binet	IQ 132
Stanford Binet 5	IQ 130
Woodcock-Johnson Test of Cognitive Abilities (**not** the Woodcock Johnson Achievement Test)	IQ 132 (editions I, II and III); IQ 131 (edition IV)

College preparatory tests

Test Name	Details	Qualifying Score
ACT Composite	taken prior to 9/1989 taken after 9/1989	29 (**composite** scores only) Not accepted
GMAT	Total percentile**	95% or above
GRE	taken prior to 5/1994 taken from 5/1994 to 9/30/2001 taken after 9/30/2001	1250 (quantitative + verbal) 1875 (quantitative + verbal + analytic) Not accepted
Henmon-Nelson		132
LSAT***	taken prior to 1982 taken after 1982	662 95 (total percentile rank)
Miller Analogies Test (MAT)	taken prior to 10/2004 taken after 10/2004	66 (raw score) 95% (total group percentile score)
PSAT (taken in junior year)	taken prior to 5/1993 taken after 5/1993	180 Not accepted
PSAT (taken in senior year)	taken prior to 5/1993 taken after 5/1993	195 Not accepted
CEEB	taken prior to 9/30/1977 taken after 10/1/1977	1300 Not accepted
SAT	taken prior to 9/30/1974 taken from 9/30/1974 to 1/31/1994	1300 1250

Tests administered by the military

Test Name	Details	Qualifying Score
AFQT	taken prior to 10/1980 taken after 10/1980	98 Not accepted
Army GCT	taken prior to 10/1980 taken after 10/1980	136 Not accepted
ASVAB		Not accepted
GT	taken prior to 10/1980 taken after 10/1980	136 Not accepted
Navy GCT	taken prior to 10/1980 taken after 10/1980	68 Not accepted

Tests administered by private psychologists

Test Name	Qualifying Score
California Test of Mental Maturity (CTMM)	IQ 132
Cattell	IQ 148
Differential Ability Scales (DAS)	GCA 132
Reynolds Intellectual Assessment Scales	IQ 130
Stanford Binet	IQ 132
Stanford Binet 5	IQ 130
Wechsler Adult and Children Scales (WAIS, WAIS-R, WAIS-III, WAIS-IV; WISC, WISC-R, WISC-III, WISC-IV, WISC-V; WPPSI ™, WPPSI-III, WPPSI-IV) **Note:** The Wechsler tests **must** be given in their entirety. - Mensa requires a Full Scale IQ score (FSIQ), so all sub-tests needed to obtain an FSIQ must be given. Supplemental sub-tests are not required unless they are substituted for a required sub-test with valid explanation for why it was substituted. - For the WISC-IV only: American Mensa will accept the general abilities index (GAI) in cases where there is a significant difference (i.e. 1½ or more standard deviations) between two index scores. For all other Wechsler tests, the GAI will not be accepted.	FSIQ 130
Wechsler Non-Verbal Scale of Ability (WNV) -American Mensa will accept the WNV test only for individuals who are hearing impaired. -The clinical report must indicate this condition to be considered.	FSIQ 130

Variations in Mensa Test Scores

As discussed in *Psychometric IQ Augmentation 2*, IQ test scores are estimates based on your test performance on a particular day. As such, there is always a margin of error. Your results on American Mensa's tests may vary slightly for any number of reasons unrelated to intelligence or the test. You may be influenced by external factors such as how much sleep you got the night before, general stress level or time of day. You may also do better on one test over another because of the type of test — analogies, verbal questions or spatial questions. One study ([ref](#)) looking at a variety of full scale IQ tests (also called 'test batteries') has concluded that:

> *"...1 in 4 individuals taking an intelligence test battery will receive an IQ more than 10 points higher or lower when taking another battery."*

The take-home is that when you take any supervised IQ test, you always have the option of taking another one, and you might expect that your score will differ by a few points, and even up to 10 points or more. This might motivate you to take multiple IQ tests for Mensa!

As Mensa explains:

> *"It is also important to note that our tests are given for the purpose of admission into Mensa and not to quantify intelligence. A qualifying score indicates that you've tested at, or better than, 98 percent of the general population."*

IQ Augmentation

Computerized Cognitive Training (CCT)

As noted in *Psychometric IQ Augmentation 2*, it has become clear from peer-reviewed research in cognitive psychology as well as neuroimaging that some types of brain training are effective for inducing long-term neuroplasticity change and increasing general intelligence (*g*) as well as, IQ scores ([reviews](#)). For instance working memory brain training such as [i3 Mindware](#) increases

IQ in both working memory (Gwm) and fluid reasoning (Gf) – as well as improving attention control.

Brain Cross-Training

Other interventions can also augment (or prevent decline of) IQ - such as aerobic exercise, phytonutrients in food, intermittent fasting, good sleep cycles, meditation, nootropics and possibly transcranial magnetic stimulation (TMS). Some of these will be reviewed in a follow-up chapters.

Getting into Mensa: Training Strategies

As noted above, Mensa accept two types of officially administered IQ tests: (i) the standard 'full scale' tests that measure different sub-factors of your intelligence including verbal and quantitative intelligence; (ii) the 'culture fair' tests that measure non-verbal reasoning and problem solving.

You can prepare for both types of test and schedule to take each, or focus on just one of them. You will need to clarify with your local Mensa organisation by phone or email which of the two tests you will be taking, and what the **subtests** for each type are. If you know the subtest names, you can do further research on them on the internet.

Note that you only need to attain a score in the 98th percentile on **one** of the tests you take - whether standard or culture-fair. Mensa loads the chances of a qualifying IQ score in your favour. You do not get your average score if you take all the Mensa tests. You can take up to a total of 5 Supervised IQ Tests for American Mensa (in the UK it is 2 tests). **Your best individual test score is what counts**.

A.   Standard Mensa Supervised IQ Test Strategy

1. Take the free **Mensa Workout** (link). This quiz is not an official IQ test to qualify you for Mensa but gives you a good idea of the range of question types involved in official IQ testing. The questions on the "Mensa Workout" are biased towards people whose primary language is English. You have half an hour to answer 30 questions.

2. Take the independent **GIQ IQ Test** (link). This test should give you a reasonable estimate of your baseline IQ. This test was reviewed in *Psychometric IQ Augmentation 2*. There is a $10 fee for scoring this test.

3. If your **baseline IQ is 130** or higher on the GIQ test, you have already scored in the top 2% of the population on this test, and are likely to already be Mensa standard. With preparation you should feel confident about taking the Supervised Mensa IQ Test. If you **scored 115-130**, you stand a good chance of reaching the 98th percentile threshold IQ score with 6-8 weeks training. If you scored **below 115** (which is classified as 'high average', then you may still choose to schedule a Supervised Mensa IQ test and work towards this. Your IQ can increase, and your IQ score can be improved considerably. But the recommendation here is to treat the Mensa admissions test date as a motivator for your cognitive training to help tap your potential - rather than having a strong expectation about getting into Mensa.

4. Read up on my previous two chapters.

5. Schedule 6-8 weeks in advance a **Supervised Mensa IQ Test** with your local Mensa organisation. This is the Mensa admissions test battery for your home country, as described above. Give yourself this period of train for the tests to optimize your performance and chances of hitting the 98th percentile.

6. Note that the **duration** of the Mensa Supervised Tests in the US is **2 hours** or more. In the UK the Cattell III B has **150 questions**. Mensa admissions tests require **mental resilience**! This is not like taking a half an hour online test. You need to get used to

focusing for 2 hours at a stretch when you are preparing for these tests. Building your mental resilience is important. You may consider setting aside 2 hours each day for mental training leading up to the admission test at the same time as you will be taking the Supervised Mensa test. How alert we are varies depending on the time of the day, so be prepared for the time-slot you are allocated.

7. Leading up to your qualifying IQ test, commit to **practicing full scale IQ test problems** from whatever sources you can find them online or in downloadable pdfs. You are looking for tests for verbal reasoning and comprehension, quantitative reasoning, and logical reasoning. It is known that this kind of practice can improve scores. The more practice you get the better. An example of an online resource for these types tests is [this website](). You are encouraged to do your own Google searches!

8. There are other **brain cross-training interventions** you can adopt over your training period to increase your brain performance and resilience. These include regular aerobic exercise, intermittent fasting and a 'brain healthy' diet - e.g. packed with phyto-nutrients. Mindfulness meditation is another strategy that can help with concentration and improve the results from your training.

9. Leading up to your qualifying IQ test, consider committing to training your **working memory capacity** (*Gwm*) and **concentration tolerance**. Working memory capacity is your mental 'workspace', and is a sub-factor of IQ. The larger the capacity, the more complex reasoning and problem solving you can do, and the more efficiently you can learn test taking strategies. There is a body of scientific evidence showing that working memory training can have widespread benefits for IQ. concentration and resilience to stress (e.g. for testing conditions) as [reviewed in this online resource.]()

[i3 Mindware]() is an evidence-based working memory training app that can improve working memory (*Gwm*), fluid reasoning and sustained concentration. The i3 app combines an advance form of dual n-back training, and comes with valid IQ tests to track your progress, and full-scale IQ test problem sets. Training with this app provides a complete training program to prepare for Mensa if you supplement the IQ test problems provided with additional online test problems.
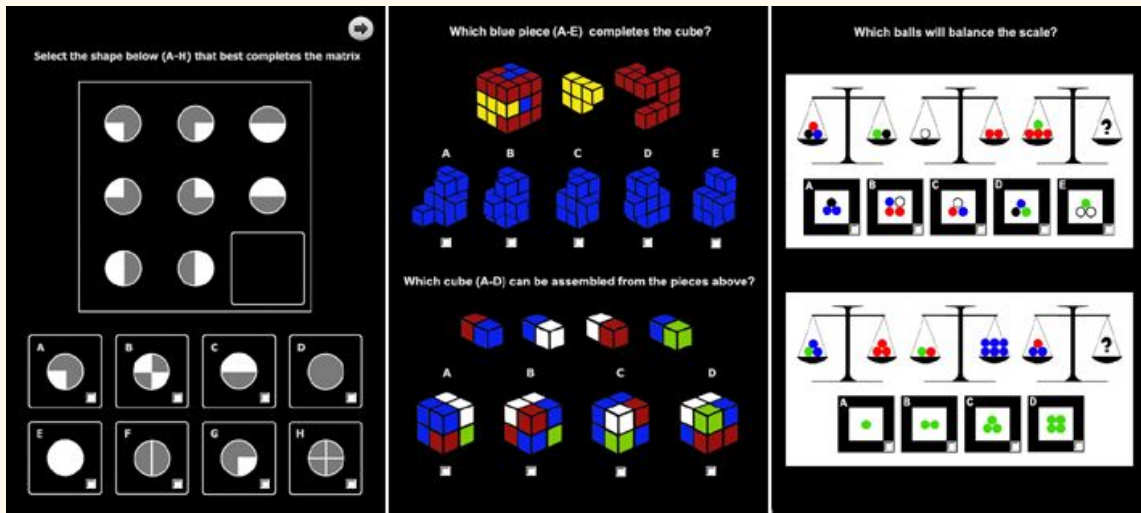
i3 Mindware IQ test problem sets

10. After completing a brain training and cross-training program – which typically lasts for 20 days minimum spread over 4-6 weeks - allow for at least two days before taking the Supervised Mensa IQ Test. And try to get a decent night's sleep before the test day.

B.   Culture-Fair Supervised Mensa IQ Test Strategy

You may choose to adopt this strategy if your first language is not English, if you are dyslexic or if you are stronger with non-verbal and non-math based IQ test problems. You could also adopt this strategy *after* taking the standard Mensa Supervised Test if you did not make the grade. You should be eligible to re-apply and take the culture-fair test the second time round. The strategy here is the same as for the Standard Supervised Mensa IQ Test above, with the following differences:

- Ensure you first contact your local Mensa organization and arrange to have the 'culture-fair' Supervised Test. You should be eligible to take this test even if you are a native English speaker, but you may need to make a specific request for this kind of non-verbal test. For contact details, see above.
- To get your initial baseline IQ scores, take any of the culture fair tests linked to in the IQ Tests chapter. These tests include Anders Jensen's IQ Test and the JCTI (Test of Induction).
- When you do your practice tests over the weeks leading up to the Supervised Test, focus on 'culture fair' IQ tests that are **not** based on verbal or quantitative

reasoning. You are looking for tests involving figures, symbols and visual patterns for fluid reasoning and visuospatial ability. Other examples of culture fair tests can be found at the following links. (Note that the scores you get will not be truly valid and standardized - do not read into the scores. The point here is to get practice in these kinds of test questions.)

> [IPS Non-Verbal Reasoning Test](#)
> [European IQ Test](#)
> [University of Kent's Non-Verbal Reasoning Test](#)

- If you use the i3 Mindware app for additional IQ augmentation brain training, you may choose to spend less time working through the verbal and quantitative IQ test problems provided.

C. Alternative IQ Test Strategy

If neither of the strategies above has worked for you, you can also opt to take one of the Mensa-accredited professional IQ tests, proctored by e.g. an HR administrator, psychologist or educationalist. These tests could be either full-scale or culture-fair, as listed in the tables of accredited IQ tests and qualifying scores above. This strategy may be preferred if you do your research and prefer some aspect of one of the authorized tests. A 6-8 week training program of the same structure as described above may then be adopted, with the provision that you train for the specific IQ test you are taking.

Summary

In summary, we have explained what valid, standardized IQ tests and scores mean in terms of the IQ Bell Curve and what a Mensa qualifying score is. We have looked at what the two basic types of Mensa admissions tests (Supervised IQ Tests) are: standard and culture fair. We have seen how the specific tests differ from country to country and how you will need to check with your home-country's Mensa organization to figure out what test options you have. We concluded by tracing out some strategies to optimize your chances of getting into Mensa - including the Standard Mensa Supervised IQ Test Strategy and the Culture-Fair Supervised Mensa IQ Test Strategy. Good luck.

5. APPLICATIONS OF IQ

Your general intelligence (*g*) as measured by psychometric IQ tests and other aspects of cognitive performance can be improved by a number of neuroplasticity strategies, including working memory and timing brain training, learning new thinking skills and strategies ('mindware'), nootropics (phytochemicals, supplements and smart drugs), exercise, intermittent fasting, meditation, and transcranial direct current stimulation (tDCS).

Before we review some of these interventions in the next chapter, I want to briefly review the 'Central Hub of Intelligence' model and some applications of this hub in our day to day lives.

Central Hub of Intelligence

General intelligence (*g*) can be defined as:

> *the capacity to think, to solve novel problems, to reason and to have knowledge of the world.* **M. Anderson**

More specifically we can define *g* in terms of the 9 CHC broad ability factors reviewed in *Psychometric IQ Augmentation 1*: Fluid reasoning/intelligence (*Gf*), Comprehension Knowledge (*Gc*) , Visuospatial processing (*Gv*), Working memory (*Gwm*), Long-term storage & Retrieval (*Glr*), Processing speed (*Gs*), Auditory processing (*Ga*), Reading & Writing (*Grw*), and Quantitative knowledge (*Gq*) ([ref](#)).

We saw in *Psychometric IQ Augmentation 2* how we can home in on an **attention control - working memory- fluid reasoning central hub** - the work of the Fronto-Parietal Network - to locate the core of general intelligence ([review](#)). We can call this the **Central Hub of Intelligence** shown in the figures below.

The Central Hub of Intelligence is also a limited capacity **bottleneck** for information processing, depending on the capacity of our Working memory (*Gwm*). There is only a limited amount of conceptual, spatial, visuospatial or numeric data we can attend to and process at any given time when we apply our intelligence.

The more we augment IQ, the greater our attention control efficiency and the more we open this bottleneck of information processing.
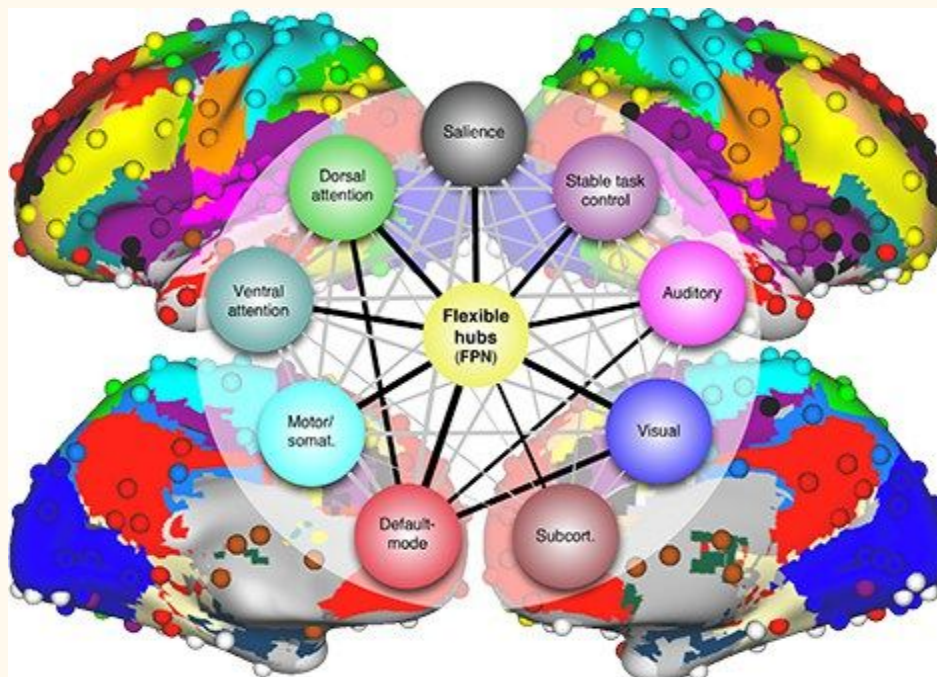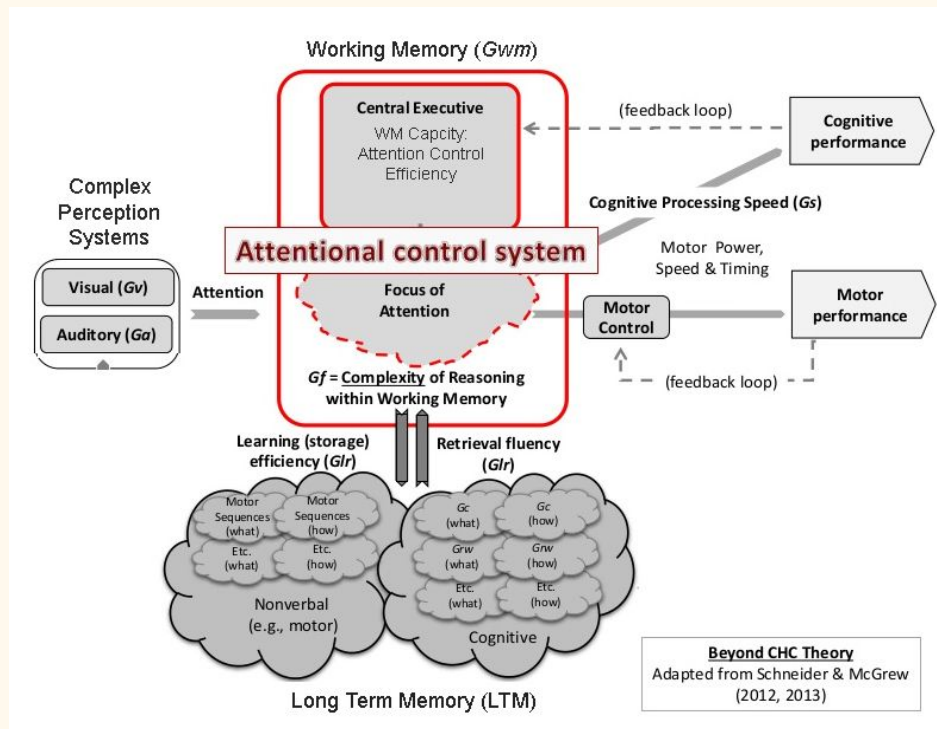
The Central Hub of Intelligence ([review](#))

While Fluid reasoning(*Gf*) is the *complexity of reasoning and problem solving* in our mental workspace of working memory, the Central Hub of Intelligence as a whole can be thought of as the seat of *flexible problem solving and adaptation to new task-demands - particularly in the face of interference.*

IQ & Cognitive Capital

There are many personal reasons why you might want to augment your IQ.

Here I want to touch on IQ in the context of our professional lives and the economy - a context that is fitting for the Central Hub Intelligence.

Dr Amanda Potter, a psychologist at the British Psychological Society informs us:

> *"We test IQ because we want to understand to what extent [people will] have learning agility and be able to take on new information, deal with ambiguity and complexity and think on their feet"*

Dr Potter is actually expressing one view of why IQ is important: being smart is **cognitive capital** in our complex, rapidly evolving, high-tech, knowledge economy – in education, training and employment.

Central Hub Intelligence is critical to adaptive, strategic and analytic thinking in which attentional focus, planning, decision-making and problem solving unfolds in the midst of change, complexity, uncertainty and distraction. Economic demands have...

> *"...increased the importance of human capital. One element of human capital is cognitive ability: quickness of mind, the ability to infer and apply patterns drawn from experience, and the ability to deal with mental complexity. Another is character and social skills: self-discipline, persistence, responsibility. And a third is actual knowledge. All of these are becoming increasingly crucial for success in the post-industrial marketplace."* **Professor Jerry Muller, 2015, Foreign Affairs**

And on the same theme from an educational perspective:

"Today, the most prominent source of economic growth lies in cognitive capital - the most democratic of assets. Cognitive capital cannot be mined or traded but rather must be carefully cultivated by the most forward-looking of policies." **Dr. Michael Samson, 2016, Director, Economic Policy Research Institute (EPRI)**.

IQ & The Attention Economy

Attention as a scarce commodity. As data and online content has grown in abundance and accessibility, attention becomes the limiting factor in the consumption of information.

Nobel Prize and Turing Award winner Herbert Simon that gets to the nub of the attention economy idea:

> *"...in an information-rich world, the wealth of information means a dearth of something else: a scarcity of whatever it is that information consumes. What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention and a need to allocate that attention efficiently among the overabundance of information sources that might consume it"* (**Simon 1971**).

Simon noted that many designers of intelligent systems (AI, information systems) incorrectly represented their design problem as *information scarcity* rather than *attention scarcity*. As a result they built systems that excelled at providing more and more information, while what was actually needed were systems good at filtering out unimportant or irrelevant information (Simon 1996).
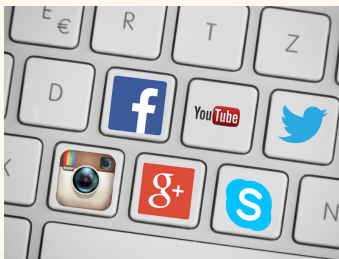
The **attention control** and **information processing bottleneck** features of the Central Hub of Intelligence are relevant here. Understanding general intelligence in terms of this model helps us see why attention filtering at the central bottleneck is critical in the Attention Economy.

Intelligence is the seat of flexible problem solving and adaptation to new task-demands *in the face of attention-consuming interference.*

IQ & Self-Regulation
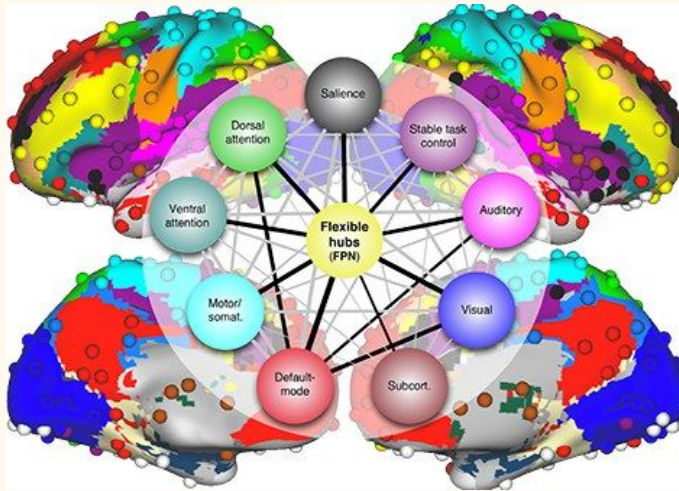
The Central Hub of Intelligence and its underlying Fronto-Parietal Network (FPN) doesn't just act as an attention filter. It also **regulates our behavior**. The FPN is also called the **Executive Control Network**. It sends out top-down 'executive' signals for **current task goals** and exerts control by flexibly biasing information flow across a lot of other large-scale brain networks ([ref](#)).

For example, if you train with the dual n-back brain training game, the better your executive control, the better your FTP switches between audio and visual brain networks (see Figure), mapping each to motor network finger presses (behavior). If your executive control is weaker, you will less flexibly switch between networks, the mappings will become inaccurate and lead to errors.
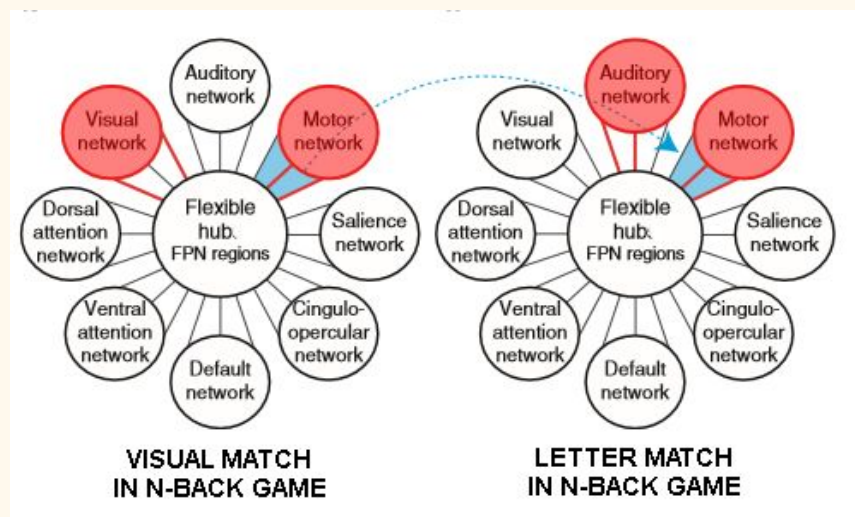
Activity of the Central Hub of Intelligence playing the Dual N-Back.

The Central Hub of Intelligence allows us to follow through with our intentions and not be on 'automatic pilot'. It allows us to overcome habits, to resist our 'default' behaviors when we need to do learn to do things differently.

To demonstrate this function of the executive hub to yourself, try to quickly read the INK colors of the words below, ignoring the actual meanings (e.g. 'red, blue, red, blue, green…'). It's your Fronto-Parietal Network and Central Hub Intelligence that allows you to overcome your cognitive habit of processing these words for their *meaning*.

BLUE   GREEN   YELLOW

PINK   RED   ORANGE

GREY   BLACK   PURPLE

TAN   WHITE   BROWN
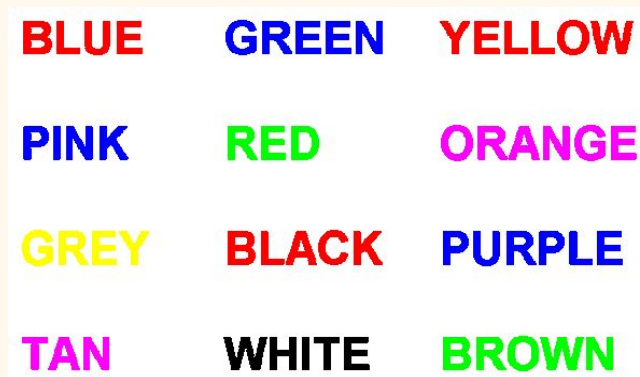
This is the well-known **Stroop Task**. Research shows a clear link between performance on this task and Fluid reasoning (*Gf*) as well as working memory capacity (*Gwm*) - all components of the Central Intelligence Hub (review).

The Central Hub of Intelligence allows us to act **rationally** when we might otherwise succumb to instant gratification. Long-term rewards are harder to motivate us than short-term rewards. It is far easier to spend $5000 now, than spend $10,000 in 30-50 years time. Your Future Self wants to have saved for retirement from your 20s or 30s; your Present Self wants to spend all surplus earnings on holidays. It's tempting to regularly binge on ice cream and cakes, when increased risk of diabetes or heart failure is years away. Your Future Self wants to remain healthy; your Present Self wants sugars and fats. Our Executive Control hub allows us to act according to more strategic, long-term commitments.

And it allows us to remain disciplined in our actions in the face of distraction in our Attention Economy. You can think of what you *do* at any given time as having a tendency to be constantly pulled in different directions.
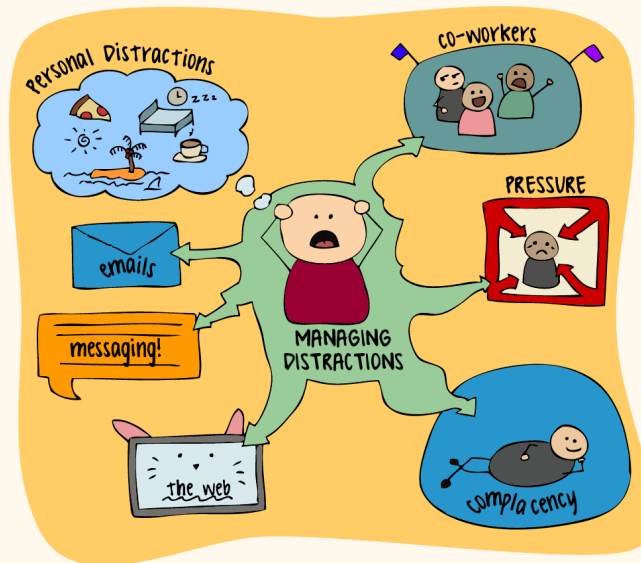
Your Central Executive hub is what prevents derailing - keeps you on track in your actions based on your goals and intentions.

The self-regulation function of Central Hub of Intelligence also extends to the **regulation of emotional reactions** that might pull at your attention and lead to unwanted behaviors For instance, when you act 'on principle' or confront someone about an issue when you don't feel like it or fear it, your Executive Control hub is engaged. It is engaged any time you are showing grit or courage.

Odysseus and the Sirens!

Self-regulation through executive control is also needed if you are prone to distraction or rumination by threats or other negative cues. For this reason, training the Executive Control Network can be particularly helpful intervention for **anxiety** or **depression** ([review](#)).

Executive control deficits are also known to play a critical role in the development and maintenance of **drug addiction** ([review](#)), and training executive control may be an effective intervention strategy for addiction ([review](#)).

Summary

In summary, we reviewed the cognitive neuroscience of the Central Hub of Intelligence, an Executive Control center, as well as the seat of fluid reasoning. We then looked at the concept of 'cognitive capital' and how this IQ hub is critical to adaptive, strategic and analytic thinking in our rapidly changing, knowledge economy. We also defined the Attention Economy, and looked at the critical filtering role of the Central Hub of Intelligence in the context of 'attention consumption'. Finally we looked at how the Central Hub of Intelligence is the 'executive control' center underlying our ability to self-regulate our actions and manage emotional reactivity.

6. Evidence Based IQ Augmentation Apps

Your general intelligence (*g*) as measured by psychometric IQ tests and other aspects of cognitive performance can be improved by a number of neuroplasticity interventions, including brain training apps, nootropics (phytochemicals, supplements and smart drugs), exercise, intermittent fasting, meditation, neurofeedback, an transcranial direct current stimulation (tDCS).

In this final chapter I review evidence-based IQ augmentation apps.

Central Hub of Intelligence

We saw in *Psychometric IQ Augmentation 2 and 5* how we can home in on an **attention control - working memory- fluid reasoning central hub** - the work of the Fronto-Parietal Network - to pinpoint the core of general intelligence ([review](#)). This is the Central Hub of Intelligence.

The brain training apps reviewed below all target this Central Hub of Intelligence.

IQ Augmentation Brain Training: A Review

We know from a largely skeptical scientific press that many brain training apps claimed to improve cognition do not work beyond practice effects. The popular scientific press has often taken an anti-brain training stance, largely because of the aversion to commercially successful companies that offer little in the way of cognitive benefits in practice.

But it has become clear from an ever-growing volume of peer-reviewed research that some types of brain training *are* effective for increasing cognitive ability and IQ.

We need to filter out the **placebo** results and hone in on those which show effectiveness under the exacting standards of placebo-controlled, double blind, laboratory studies - those that meet the exacting standards of **peer-reviewed scientific journals**.

It is apparent that the brain training apps that work most effectively target Central Hub Intelligence neuroplasticity.

Working Memory Brain Training

"The results of individual studies encourage optimism regarding the value of working memory training as a tool for general cognitive enhancement." [Morrison & Chein review](#).

Working memory (*Gwm*) is one of the broad abilities of general intelligence. It is your 'mental workspace' – the limited amount of content (verbal, spatial, images) you can process 'online' and focus on for problem solving, reasoning, planning, comprehending & decision-making. Working memory is **limited capacity** - you can only activate *some* information from all the knowledge and memories held in your long term memory at any given time.
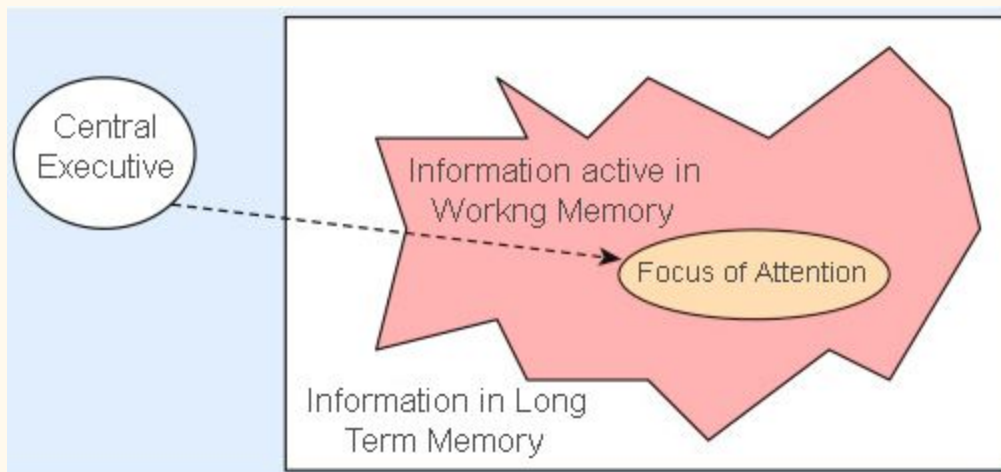
Cowan's model of working memory (1988) ([ref](#))

Dual N-Back

One of the most well-known working memory training methods is the **dual n-back**. This is a game that involves keeping track of continuously changing audio letters and shape locations, and responding when there is a match 'n' times back in the sequence - as shown here.
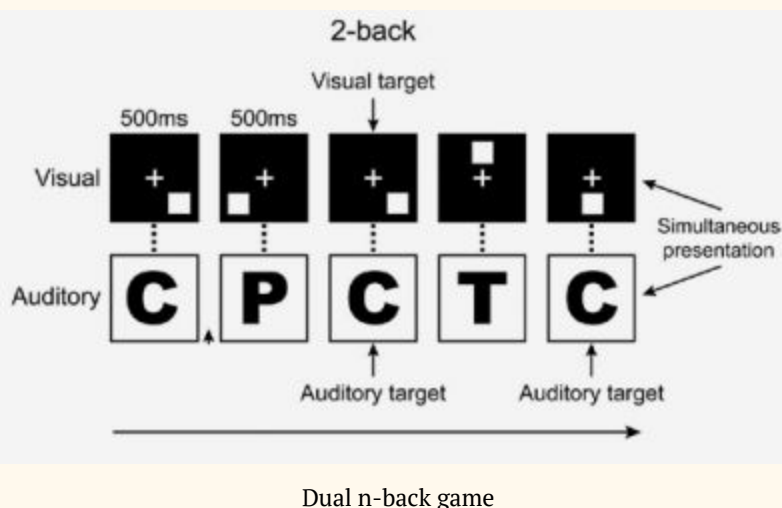
Dual n-back game

This figure shows a 2-back game. The game is *adaptive* so that if you get good at this, you go up to a 3-back, 4-back, 5-back and so on.

Have a look at this October 17th 2017 Johns Hopkins University press release about a study published that week on dual n-back training. The study was published in the Journal of Cognitive Enhancement and can be found here Johns Hopkins researchers suspected the problem wasn't the idea of effective brain training, but the type of training exercise researchers chose to use.

The training exercises Johns Hopkins compared are not the commercial products typically available and sold to consumers, but a lab-designed dual n-back.

There were three groups in the study: One group trained with the **dual n-back**, another group trained with another working memory exercise called the **symmetry span task**, and a third (control) group trained with a challenging **verbal logic task** that did not involve working memory. Everyone took a round of cognitive tests, trained five days a week for 30 minutes, then returned to the lab for another round of tests - including brain EEG recordings - to see if anything about their brain or cognitive abilities had changed.

The researchers found that the group that practiced the dual n-back exercise showed a **30% improvement in their working memory** - a core component of Central Hub Intelligence. That was nearly double the gains made by the group working with the other working memory exercise.

The dual n-back group also showed significant changes in brain activity in the **prefrontal cortex**, the critical region responsible for general intelligence.
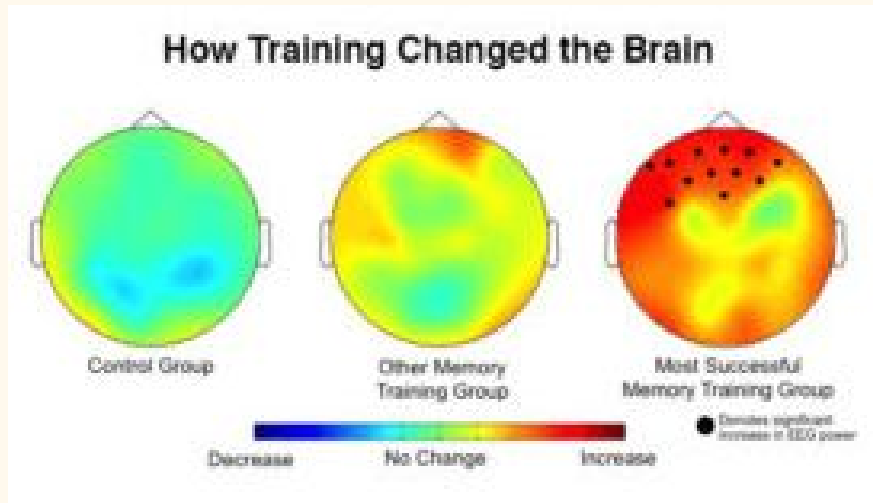
This Johns Hopkins' study adds to the message of the multiple brain imaging studies ([ref 1](#), [ref 2](#), [ref 3](#)) showing **neuroplasticity change** in the the **Fronto-Parietal Network (FPN)** as a result of dual n-back training. As we reviewed in *Psychometric IQ Augmentation 2*, the FPN is the brain's 'control hub' underlying Central Hub Intelligence. This neural network sends out top down signals for current task goals and exerts control by flexibly biasing information flow across multiple large-scale functional networks. The FPN is a key network underlying intelligent, goal directed action and learning.
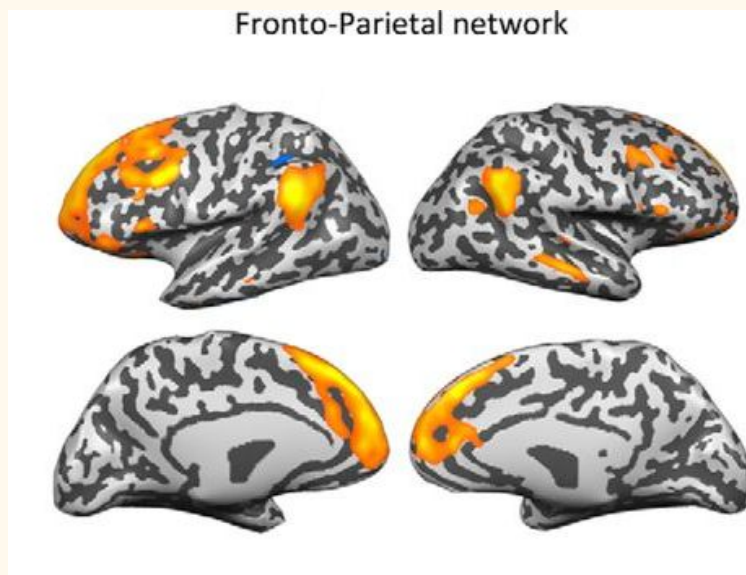
(Views from outside and inside of both hemispheres)

Cognitive neuroscience and neuroimaging research has demonstrated the following as a result of dual n-back training:

1. **Functional connectivity** within the Fronto-Parietal Network increases following training, and the magnitude of increased connectivity is tied to improvements in task performance ([ref](ref)).
2. Working memory training **increases grey matter volume** in the Fronto-Parietal Network ([ref](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](ref1), [ref2](ref2)).

This Johns Hopkins study also adds to the **dual n-back behavioral studies** that have been analyzed in recent 'meta-reviews'. The conclusion of these reviews is that there are real IQ augmenting training effects of DNB brain training beyond placebo effects and just getting good at the n-back game itself through practice (review 1, review 2).

The very latest 2017 meta-review of 33 published, randomized, controlled DNB trials from independent labs all around the world (review) finds there are real (non-placebo) training effects of DNB brain training on:

- Other n-back games - the biggest effect
- Working memory (*Gwm*)
- Fluid reasoning / Fluid intelligence (*Gf*)
- Attention Control

Working Memory Training Revisited: A Multi-level Meta-analysis of N-back Training Studies
Soveri, Antfolk, Karlsson, Salo & Laine (2017). Psychonomic Bulletin & Review

Untrained N-back Tasks

Working Memory

Fluid Intelligence

Cognitive Control

Training Effects
(Hedge's g)

(0.0)   (0.2)   (0.6)
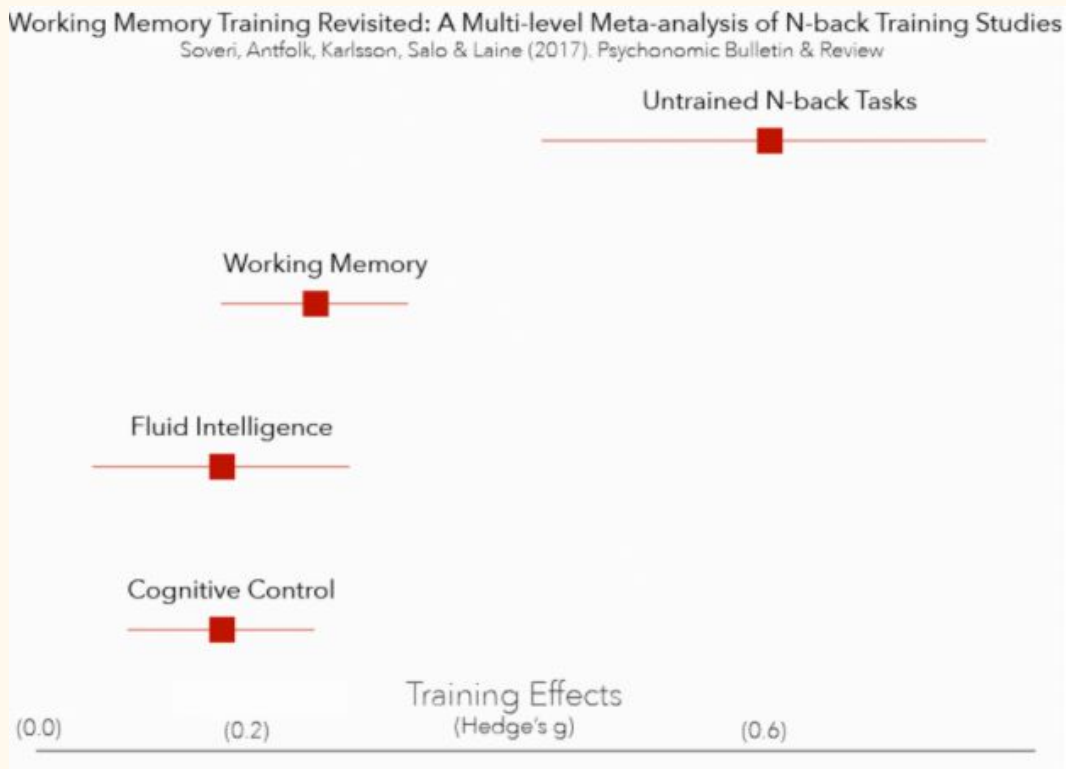
Training effect sizes of the dual n-back game

How can we interpret these 'training effects'? The effect size for working memory capacity (**Gwm**) is 0.24. Let's take another kind of intervention to compare. 0.24 is the same effect size of antidepressants such as Fluoxetine in treating depression (ref). Certainly a lot is invested into developing anti-depressants. So we should take notice of this kind of effect size when it comes to augmenting IQ.

While dual n-back benefits for working memory (**Gwm**) have been consistently demonstrated, there has been controversy concerning dual n-back training benefits for **Fluid reasoning** ability (also called 'fluid intelligence'), but the weight of the evidence indicates otherwise as you can see. The effect is small but real. Dr Au and colleagues' earlier 2015 meta-analysis also found the same effect size of dual n-back brain training on fluid reasoning (ref), and they argue:

> *"the results reported in this meta-analysis represent a low-end estimate of the true extent of improvement that n-back training can have on measures of fluid intelligence."*

So we have two independent groups, reviewing all the available evidence on DNB training, coming to the same conclusion about training benefits for Fluid reasoning (*Gf*), as measured by matrices IQ tests.

In conclusion, dual n-back training works. It improves IQ through neuroplasticity change, and it does so to a useful extent.

There are multiple n-back apps available online ([i3 Mindware](#) is one). Ensure that you choose one that implements a lab-tested program and that you commit to program completion.

Cognitive Control Training (CCT)

The standard dual n-back is a **working memory** (*Gwm*) training intervention; it trains working memory **updating**. The dual n-back js not designed to train **executive attention control functions.**

There is another class of brain training interventions called **executive control training** or **cognitive control training (CCT)**, specifically designed to activate areas of the brain that allow us to control and direct our attention and adjust our thoughts and actions when confronted with conflict during information processing. Due to central role of attention control in the Central Hub of Intelligence, this training strategy makes a lot of sense for IQ augmentation.

Dual N-Back with Interference Control Training

The Central Hub of Intelligence can be thought of as the seat of flexible problem solving and adaptation to new task-demands in the face of interference or information conflict. **Interference control** is the ability to filter out distracting information that attracts attention and resolve information-conflict. Interference control is of particular value in our Attention Economy, where all-pervasive information continually consumes the scarce resource of our attention, and where there is a need to filter out distractions and resolve information conflicts as we pursue our goals and projects.

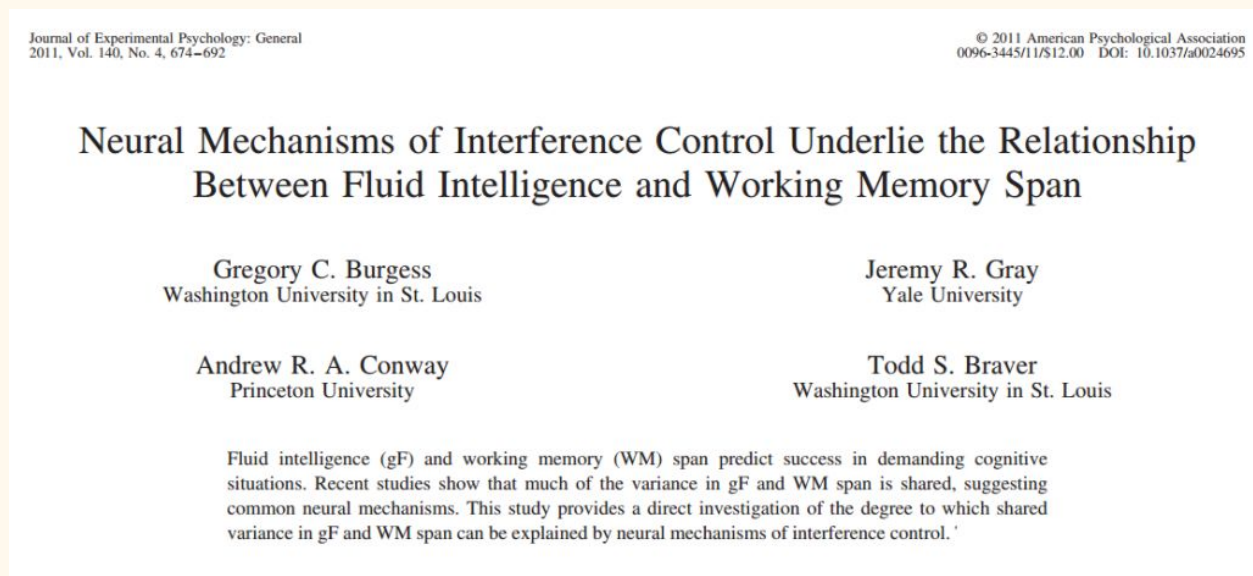The first study that looked at the dual n-back with built-in interference control training found that compared to the standard dual n-back interference training resulted in improved attention control ([ref](#)). It also resulted in increased electrical signalling in the parietal cortex (part of the Fronto-Parietal Network). This, they concluded:

> *"may be related to improvements in processing speed, attentional control, or both"*

In a recent 2017 study, dual n-back *and* interference control training - compared to standard dual n-back training - resulted in improvements in both memory and language ([ref](#)). The researchers conclude:

> *"domain-general cognitive control mechanisms are plastic...and may play a causal role in linguistic and nonlinguistic performance"*

Neuroimaging research shows that interference control underlies the link between fluid reasoning/intelligence (**Gf**) and working memory (**Gwm**) ([ref 1](#), [ref 2](#)).

Journal of Experimental Psychology: General
2011, Vol. 140, No. 4, 674–692

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0096-3445/11/$12.00   DOI: 10.1037/a0024695

Neural Mechanisms of Interference Control Underlie the Relationship Between Fluid Intelligence and Working Memory Span

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Washington University in St. Louis

Jeremy R. Gray
Yale University

Andrew R. A. Conway
Princeton University

Todd S. Braver
Washington University in St. Louis

Fluid intelligence (gF) and working memory (WM) span predict success in demanding cognitive situations. Recent studies show that much of the variance in gF and WM span is shared, suggesting common neural mechanisms. This study provides a direct investigation of the degree to which shared variance in gF and WM span can be explained by neural mechanisms of interference control.'

Note that 'fluid intelligence' is fluid reasoning ability

Interference control training is built into some dual n-back game apps (e.g. [i3 Mindware](#), [Dual N-Back Pro](#) & Brain Workshop) through carefully designed sequencing of the stimuli to create information conflict. What has been a target for a while suddenly switches to becoming a distraction in the game, requiring that you exert attention control to stop responding to it. This makes the dual n-back more challenging, and provides more effective training.
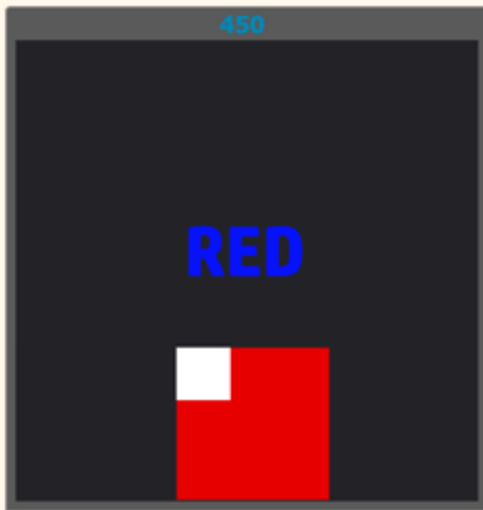
[i3 Mindware](#) and [HighIQPro](#) games also include the 'Stroop' n-back' based on the Stroop Task) - a variation of the dual n-back in which you need to ignore the *meaning* of words (red in the example here), and just respond to matches of the words' colour (blue). To get a feeling for the interference control needed for this n-back task, try quickly saying the ink colours, ignoring the color names, in this set of words. This is the Stroop Task.
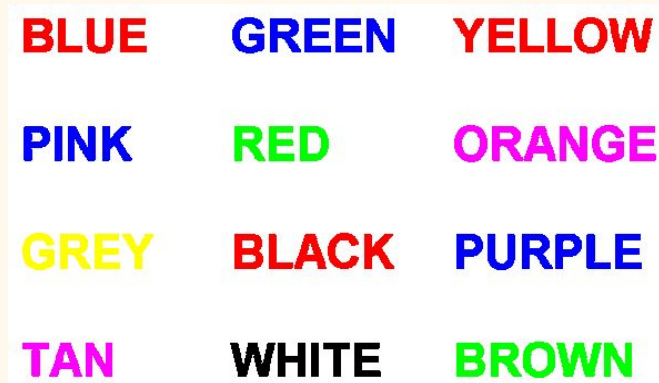
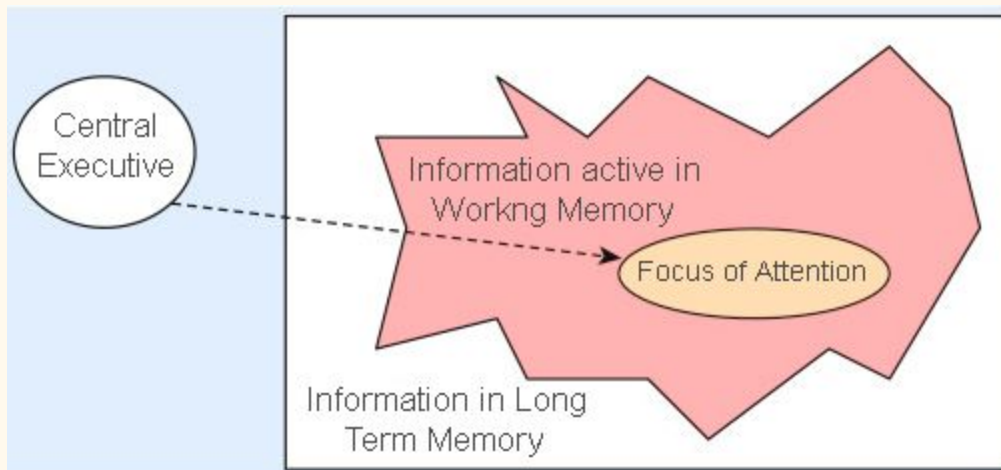### Task Switching & Selective Attention Training

Another cognitive control task developed for improving attention control and broader measures of intelligence is **task switching** ([review](#)).

Task switching training involves having to selectively attend to only *some* features of the information available to your senses (ignoring others) to perform a task, and then flexibly changing the features you attend to based on an updated rule set. The rules of the game change unpredictably based on some cue. Three studies looking at the benefits of task switching training compared the effects of training children (8–10), young adults (18–26) and older adults (62–76), and found training benefits for untrained executive control tasks and fluid intelligence (*Gf*) across all age groups ([review](#)).

Executive control selective attention and task-switching training is implemented in the i3 Mindware and HighIQPro brain training apps in their 'gated' dual n-back games. **Input gating**, for example, requires the flexible switching between four streams of information rather than the standard two (audio and visual) in the dual n-back.

Output Gating Training

Not all information that you are keeping 'online' in the mental workspace of working memory may be useful for what you are currently trying to do. For instance, you need to apply the instructions you're holding in working memory, just one step at a time. In Cohen's model of working memory shown below, you can see that the focus of attention at any given moment selects from all the information that is active in working memory

This kind of selection from workspace information depends on another executive control function called working memory **output gating**. Studies have shown that output gating, like selective attention and task switching, depends on the Fronto-Parietal Network (as well as corticobasal ganglia circuits)(ref, review).

Output gating is particularly important for the application and learning of abstract, higher order rules - precisely what is needed for psychometric IQ. It is needed for all these IQ-related abilities (ref1, ref2, ref3):

● Applying complex rules

● Generalization and learning from single cases

- Complex reasoning

- Complex decision making

- Complex planning

i3 Mindware and HighIQPro are the only apps on the market incorporating output gating brain training.

For those already familiar with the dual n-back training, the output gating is shown below. In the top panel sequence the 'division' cue tells you to only respond for a 2-back match when either the location or the letter match on their own but not when they both match at the same time. In the bottom panel the 'equals' cue tells you to only respond for the 2-back match when there is a location and letter match at the same time, but not when either of them matches on its own.
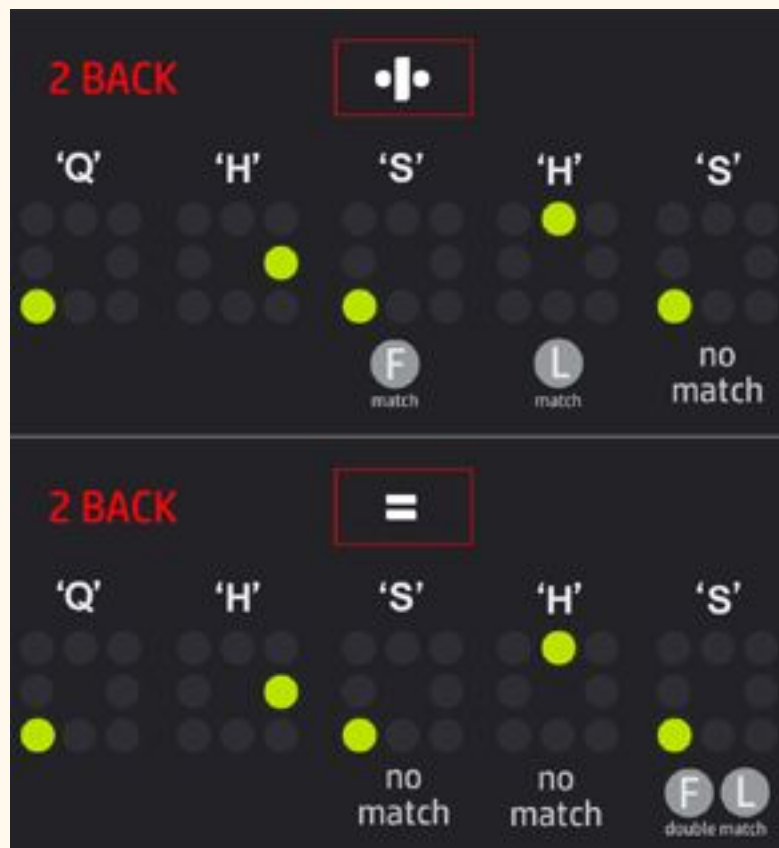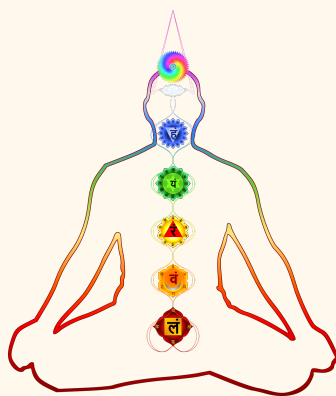

Example sequences for output gating in the dual n-back

Sustained Attention Training

Sustained attention training involves:

- sustained attention to a target
- disengaging from a distracting object (attention switching)
- redirecting focus to the target (selective attention)

In **focused attention mindfulness meditation**, the 'target' can be awareness of breathing (ref). This sustained attention mindfulness practice has been shown to result in improvements in diverse attention functions, as well as the Stroop task and working memory (*Gwm*) performance. Cognitive neuroscience studies have found changes in activity of the cingulate cortex and other frontal areas, known to be involved in interference control and resolving information conflict - part of the Fronto-Parietal Network and Central Hub of Intelligence (review).

A sustained attention computer game with neurofeedback that adapts in difficulty like the dual n-back has also been shown to improve sustained attention and vigilance, with fewer attention lapses (ref, ref).

Useful Field of View / Processing Speed Training

Useful Field of View (UFV) training is a game that exercises central executive attention control but also speed of processing and sensory discrimination. The game involves quickly discriminating between stimuli in the center of your attentional focus, while also scanning for targets in the periphery of your vision among distractors. You can imagine a real world equivalent of this task when driving - having to divide your attention between what you are currently focusing on (e.g. an exit sign) while also keeping situationally aware of the traffic around you.

The UFV exercise has been studied for thirty years (review). Most of these studies have been conducted on older people (60 years plus). But also middle aged (ref) and younger adult (ref) population studies have been conducted too. The conclusions of a comprehensive 2017 meta-review of all these UFOV studies (review) concludes:

- Useful Field of View training improves neural outcomes, speed of processing, and attention.
- Useful Field of View training improves older adults' everyday function.
- Improvements from Useful Field of View training endure across ten years.

Useful Field of View training is currently available in the 'Double Decision' game of the company *BrainHQ*.

Summary

I have reviewed a number of evidence-based brain training games and apps, focusing on interventions that result in neuroplasticity change in the Fronto-Parietal Network and the Central Hub of Intelligence. These include games implementing the dual n-back, interference control, as well as a number of other cognitive control games that target attention control and resolving information conflict. I also reviewed sustained attention and Useful Field of View brain training interventions.

Training with these apps can improve your baseline psychometric IQ and Executive Control functions such as attention focus and flexibility.