VECTORIZING YOUR IQ

How to Become Smarter Through Science

Dr Mark Ashton Smith IQ Mindware.com

Vectorizing Your IQ. How To Become Smarter Through Science

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www.iqmindware.com

Dedication

This book is dedicated to my Cambridge University colleagues in the Department of Psychology who, during my Cambridge years, provided me with the motivation to actively pursue my own independent research goals.

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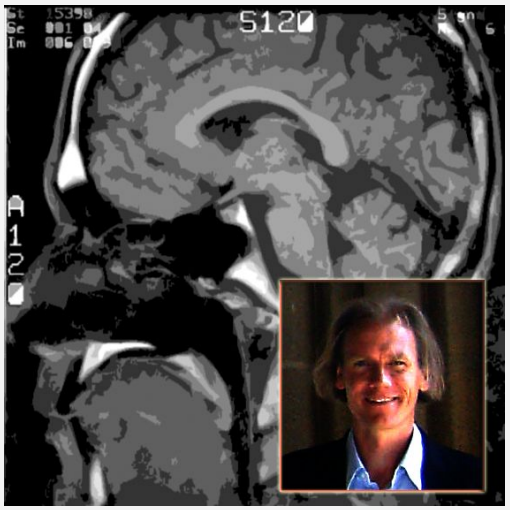
Unit 1

Mark Ashton Smith, Ph.D.

Let me introduce myself for some context.



I'm Dr. Mark Ashton Smith, applied cognitive neuroscientist and founder and director of IQ Mindware – an evidence- based cognitive training provider.

I earned my joint neuroscience and cognitive psychology PhD at the Carnegie Mellon & University of Pittsburgh's Center for the Neural Basis of Cognition (CNBC) program. This was one of the first cognitive neuroscience programs in the early 1990s. Its graduates have gone on to be leaders in the field. My fellow CNBC graduate students Professor Tod Braver, Professor Randall O'Reilly, and Professor Jason Chein have all spearheaded seminal research in intelligence and the brain's executive functions - and some of this research has fed directly into the development of my IQ augmentation apps and courses.

I worked as a Lecturer (Assist. Professor) and researcher in the Department of Psychology at Cambridge University for a number of years and

went on to help build and direct psychology programs around the world.

I now use my scientific training to develop evidence-based apps and programs to help people get smarter and build cognitive resilience. I maintain an active research program as Director of the Cambridge Mindware Lab with researchers in labs around the world, testing my apps in real-world settings. I have worked with many successful professionals as well as government organisations, universities and corporations.

I am also on the faculty of the Department of Psychology, University of Essex Online, creating online BSc degree courses and lecturing undergraduates.

In my spare time I am a competitive paraglider pilot, while enjoying a wide range of interests from philosophy of science to multi-player online video games with my daughter.

Who Is This Book For?

This book is for anyone who is motivated to improve their cognitive capacity - their intelligence, brain power or IQ.

You could be someone who feels the pressure of a **capacity gap** - that your IQ, brain power or mental ability needs to be augmented to meet the cognitive challenges life presents to you - whether through demands at college or work. Or you feel like you are not as sharp, mentally agile or as productive as you were when you were younger.

Or you could be someone who has set themselves a cognitively demanding **challenge** such as joining Mensa, learning a new language or writing a book, that demands a lot from you - cognitively, creatively and motivationally. The more 'brain power' you have for this challenge, and the more efficient you are in your processing power, the better.

Or perhaps you are someone who simply wants to **become a better version of yourself** - just as you may want more physical fitness and capability, you may want more brain fitness and intellectual capability - to become better, stronger and faster.

Whatever your motives, if you're like many people, you will think your IQ level is fixed in stone.

General intelligence is genetically hardwired the story goes, and there is little you can do to change it. Some people are naturally smart: they learn quickly, grasp complex matters, problem solve effectively.

While others either don't have the capacity at all, or have to work harder and practice more, relying on their desire to succeed to keep up to speed.

Through the next Units of this Ebook I am going to lay out the evidence for you that your IQ is not fixed: that with the right interventions and choices you can augment your raw brain power dramatically.

Knowledge is power. Before reviewing the evidence, I'm going to provide you with an educational roadmap of what IQ and general intelligence actually is, and how it functions.

> it's not always the people who start out the smartest who end up the smartest.
>
> — Carol S. Dweck, *Mindset: How You Can Fulfil Your Potential*

Vectorizing Your IQ: The Concept

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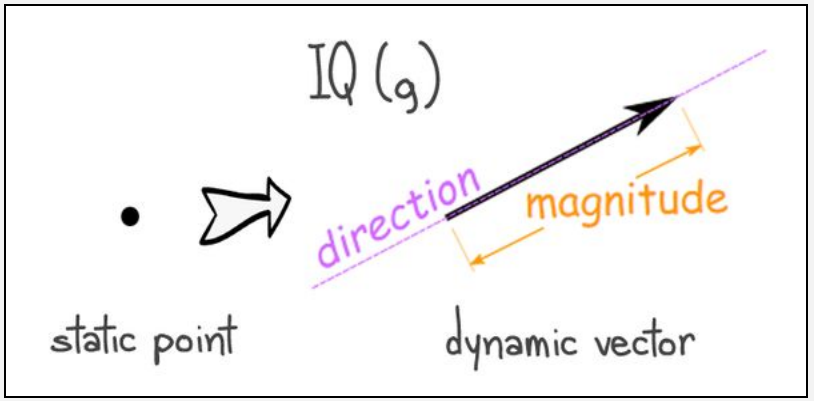
The title of this Ebook is *Vectorizing Your IQ*. Vectorizing your IQ means changing your understanding of your IQ as static and flat-lining (or down-sliding) through the years, to understanding IQ as a dynamic capacity that can have upwards momentum. Vectorizing IQ is a central mission of IQ Mindware.



Vectorizing your IQ

Vectorizing your IQ involves a **3 step process**.

Step 1

Step 1 is **educational**. If you take a valid IQ test you get a standardized test score. Let's say it's 110 - that's 10 points higher than the average IQ test score of 100. This (current) IQ score is a measure of the *g* factor - or simply *g*. Step 1 of this course covers understanding *g* and the nature of general intelligence from a scientifically informed point of view.

Step 2

This step is designed to be **motivational**. It involves you reviewing the evidence, so you can make your own mind up about: (1) The value of a higher IQ - what impact another 10-20 points of IQ might have in your life? (2) Whether you believe - based on the evidence - it is realistic and cost-effective to raise your own IQ and cognitive ability through evidence-based interventions and changes in your habits and environment. (3) If you are convinced, the kind of results in terms of IQ test scores or real-life outcomes you can realistically expect.

Step 3

This step aims at **committed training**. It comes into play when - based on your own evaluation and decision - you commit to an IQ augmentation program - whether evidence-based app brain training or other brain cross-training strategies, such as nootropics, meditation, intermittent fasting, and so on.

Let's begin now with Step 1.

What is IQ? Working Definitions

Here are some working definitions of general intelligence - measured by IQ tests - for a useful starting point. (1) A consensus-definition of fifty-two intelligence researchers defines intelligence as:

> *"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."*

From artificial intelligence (AI) we get these definitions of intelligence:

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

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

And in the context of our careers and professional lives we have these definitions of intelligence:

“ 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.” R. Sternberg

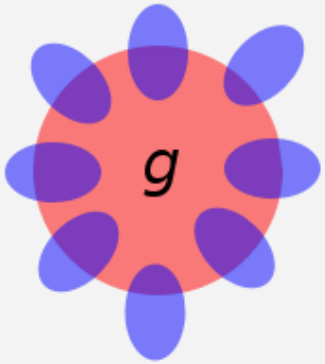
Understanding general intelligence depends on understanding ***g*** and understanding *g* depends on understanding the **positive manifold**.

The English psychologist Charles Spearman in the early 1900s saw that childrens’ school performance across seemingly unrelated school subjects – from history to languages to science – were all **positively correlated**. Scores tended to rise and fall together across the board. He called this the ‘positive manifold’.

The positive manifold is a well-established fact: averaged over enough people, performance on all cognitively demanding tests, often with very different content – from languages to math, from SATs to music theory exams – are positively correlated.

Many consider the positive manifold the best established and the most striking fact in the study of intelligence.

The great intelligence scholar Jensen called it "simply a fact of nature" and some have called it "the first law of intelligence."



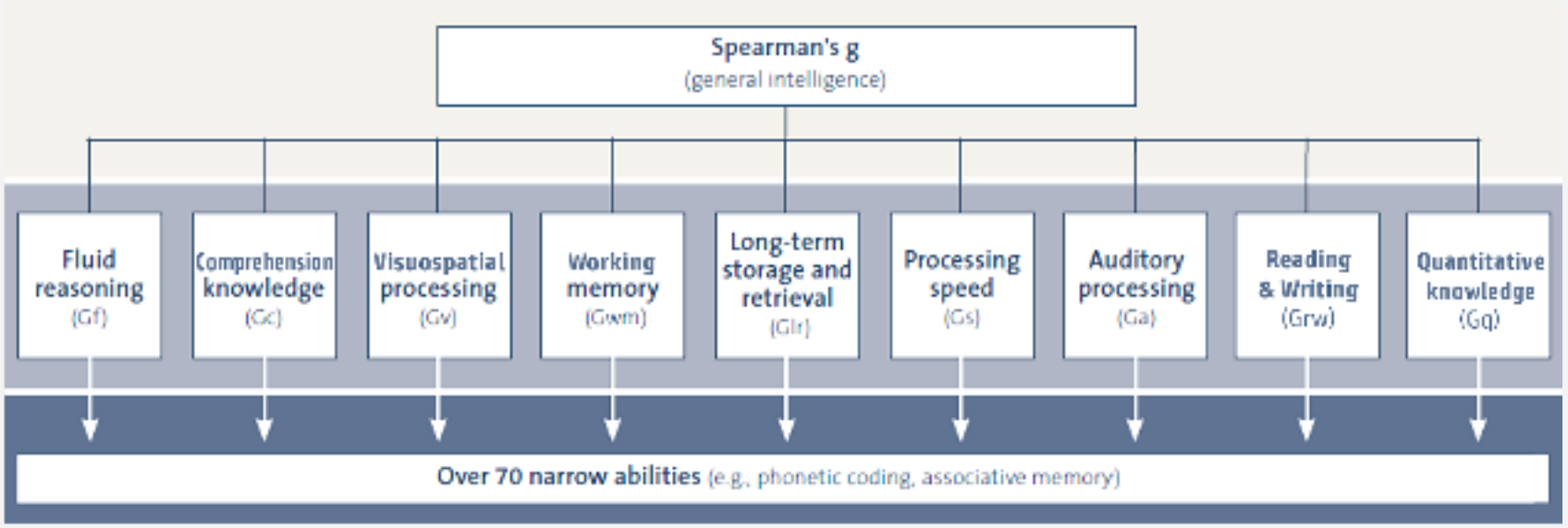
Spearman explained the positive manifold by proposing a universal **general ability factor** – ***g*** that is common to scores on all cognitive tasks.

The terms IQ, general intelligence, general ability and *g*, are used interchangeably to refer to this common core shared by a wide range of cognitive tasks.

Subfactors of G

The well-established **CHC** (Cattell-Horn-Carroll) theory of general intelligence uses a statistical technique called **factor analysis** to reveal a second level of 'broad ability' subfactors below the *g* factor. These include visual processing (Gv), comprehension -knowledge (Gc), fluid reasoning (Gf) and processing speed (Gs). (2)

The original 9 broad abilities in CHC Theory are shown in the diagram below. (Others have since been identified by including psychomotor ability (Gp) and emotional intelligence (Gei).)

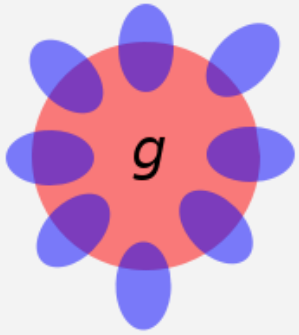


Actionable: Have a look at the above 'multiple intelligences' and consider if you have relative strengths or weaknesses in them.

Someone may be relatively strong at visuospatial but weak at processing speed, while someone else may have the reverse pattern - even though they may both have the same level of general intelligence (*g*). Like a snapshot of peaks and troughs of the sea at different tide levels - *g* is the baseline tide level and the peaks and troughs are variation in broad abilities.

These can be called 'multiple intelligences' provided it's understood that they are all tied to the general factor and tend - on average - to rise and fall with it.

And there's more to absorb...



Some broad IQ abilities *load* more highly on *g* than others: they are more closely associated (overlap more) as you can see with the blue ovals here. This means that they are more closely correlated with the *g* factor as well as all other cognitive tasks and tests. They are in this way more representative of the general intelligence (*g*) factor itself.

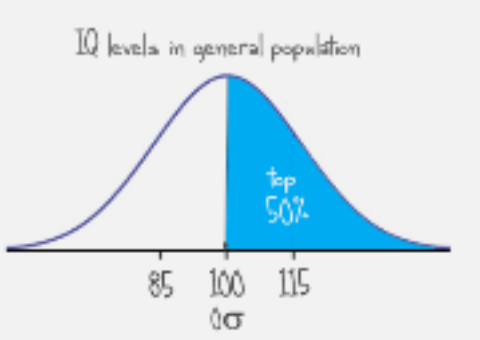
As we'll see, two types of broad ability load highly on *g*: **fluid intelligence** (Gf) - also called fluid reasoning - and **working memory** (Gwm)

IQ Tests

IQ tests are designed to measure ***g*** – the **general intelligence factor** underlying the positive manifold. Your IQ is a **standardized measure of**

g, where the average is 100 and the spread of scores in the general population looks like this 'bell curve'.

Using this bell curve we can define 'high IQs' as being in the top 16% of the population – with IQs above 115.



Full Scale IQ tests

Six of the broad abilities (Gf, Gwm, Gc, Gs, Gv and Gq) in the CHC theory load quite highly on *g*.

These are measured by subtests of **full-scale IQ tests**. When you take a full scale IQ test, you get both a **composite IQ score** (measuring *g*), as well as **subfactor scores** - showing relative strengths and weaknesses of the broad abilities such as visuospatial vs verbal.

CULTURE FAIR (GF) IQ TESTS

The broad ability with the **highest *g*-loading** is fluid intelligence (Gf). (3)

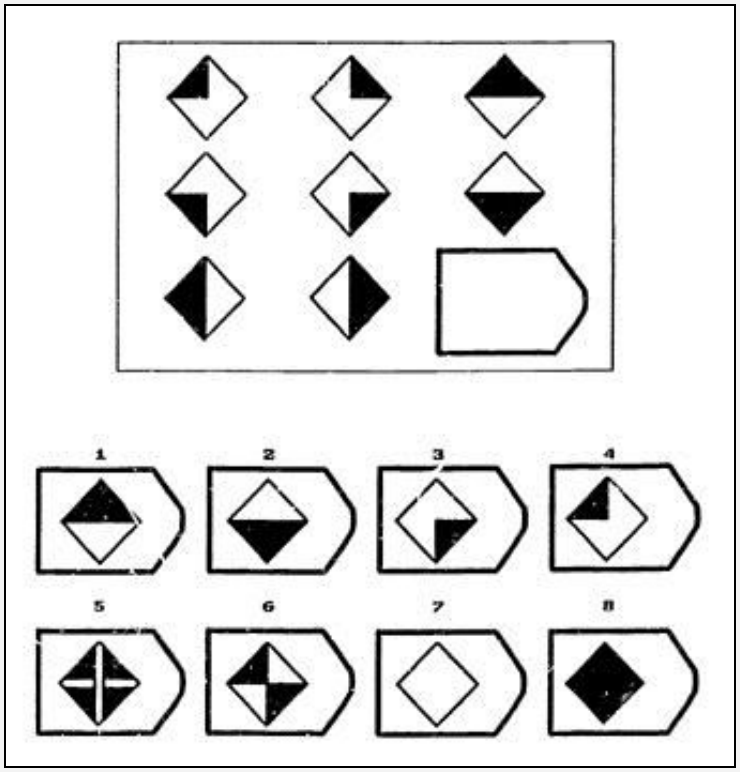
Gf tests - sometimes called 'culture fair' IQ tests - such as Raven's Matrices tests or number/letter series tests (see below) - assess your power of reasoning (inductive and deductive) and your ability to infer patterns, relationships and rules without the need for specialized cultural knowledge or education.

We're talking very general-purpose information processing skills here.

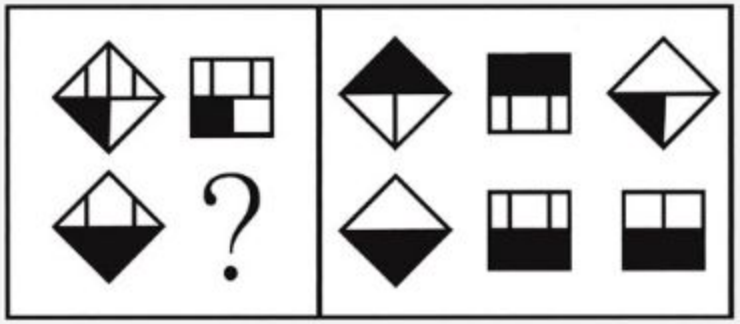
These tests load so highly on ***g*** that they can be used as a **substitute** for full-scale IQ tests. If you do a matrices or letter series test, you get a good estimate of your general intelligence (*g*) from this test alone.

Actionable: Here are two examples of matrices IQ test problems.. Each question consists of a design that has a missing piece, followed by six to eight figures, one of which is the missing piece. You must look for similarities and differences across the rows and down the columns of the design in order to find the piece that fits.

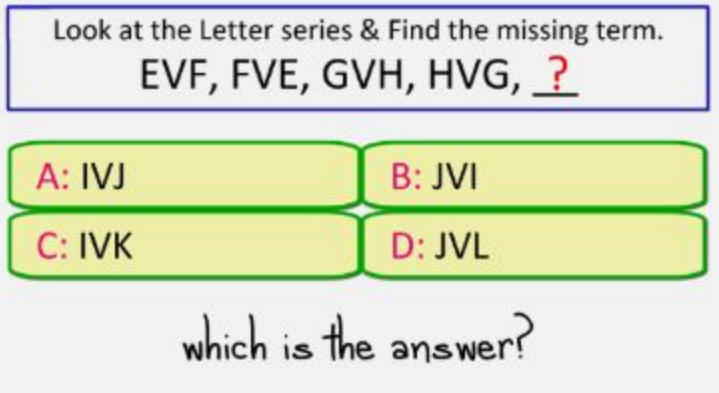
Try figuring out (literally!) the answers.



And for a more challenging matrix problem.



And here's a letter-series problem from a Gf IQ test. Try finding the answer.



With these problems, you now even have a feel for what kind of processing your brain is doing when you engage your fluid reasoning and thus *g* directly.

How did you get on?

The answers are: 8, bottom right, A.

Working Memory

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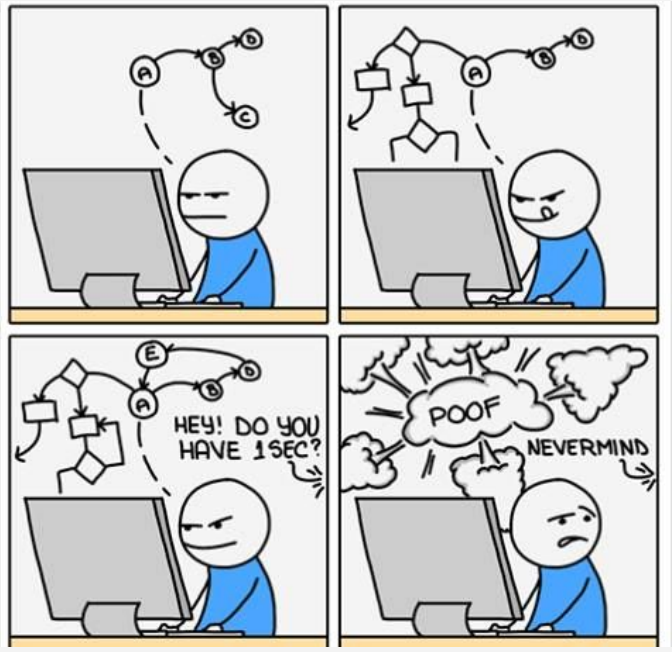
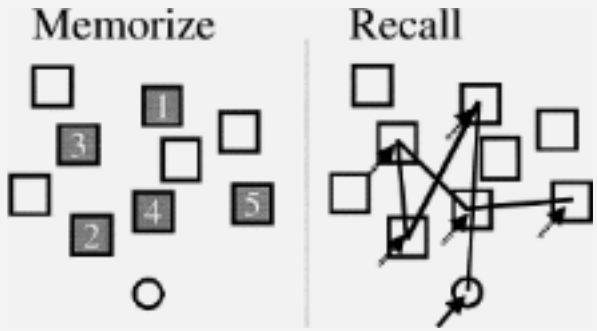
Working memory (Gwm) is another broad ability that loads highly on *g*. And many studies have shown working memory predicts fluid intelligence to a high extent; in some studies they appear to be virtually the same ability. (4)

In combination with attention control, your working memory functions like a mental workspace. Its job is to temporarily store task-relevant information for ongoing information processing while inhibiting distractors or automatic responses.



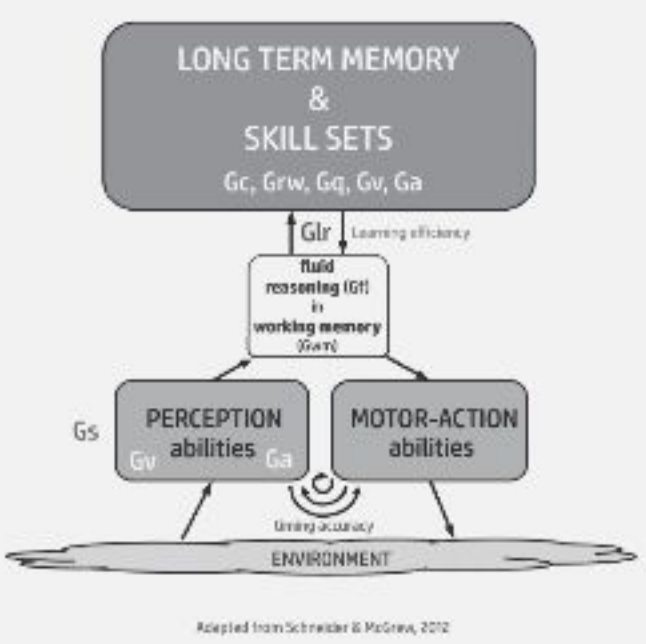
People differ in the **capacity** or 'bandwidth' of their working memory. Differences in working memory capacity (WMC) strongly predict IQ levels. The **n-back** is a task used to measure WMC.



WM Test: Boxes flash in sequence. You have to remember the sequence.

So why do both Gf and Gwm overlap with the *g* factor and each other so well?

To answer this we need to look to research that explains how broad IQ abilities identified in CHC theory work together in an **information processing model for general intelligence** (*g*) - such as this one by Schneider & McGrew. (5)



Adapted from Schneider & McGrew, 2012

You can see in this model that fluid intelligence and working memory operate together as a kind of limited capacity **central processor** of our

intelligence. Our reasoning and inference-making plays out in the mental workspace of our Gwm. The larger the capacity of our Gwm, the more the 'bandwidth' we have for fluid reasoning, making inferences and seeing patterns.

This Gf-Gwm central processor of IQ acts as a limited capacity **bottleneck** between the vast stores of knowledge in our long-term memory and our skilled capacity to perceive and act on the world around us. You might have deep and extensive knowledge and skill sets encoded in your long-term memory but unless you have the ability to access it and the bandwidth to apply it to the challenge you face right now, you will not manifest a high IQ.

So you can begin to see why Gf and Gwm are related, and why they predict overall intelligence levels so well.

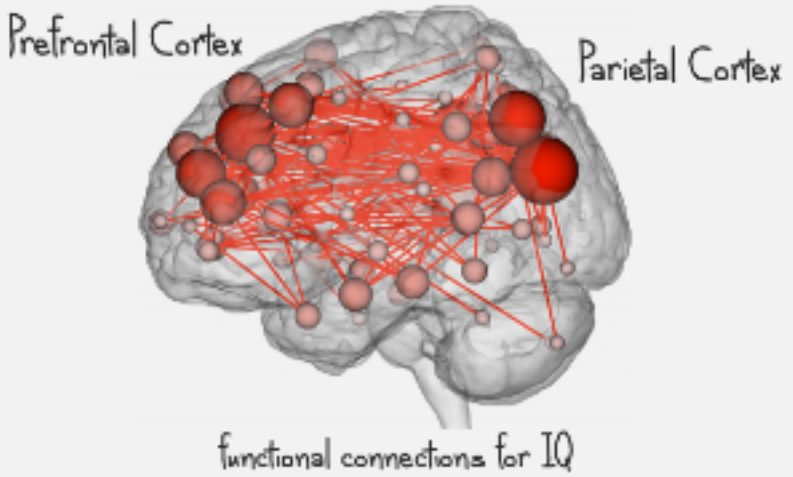
Where is G in Our Brains?

We can now rephrase this: Where is the Gf-Gwm central processor in our brain?

Some brain regions are highly connected, acting as **flexible network hubs**. These have a central role in supporting integrated brain function and multiple learning and thinking demands. (6)

Brain imaging studies have shown time and again that IQ-intensive, *g*-loaded tasks all depend on

neural signalling in the prefrontal and parietal lobes of the brain. (6)



Working memory-intensive fluid intelligence has identified with a network hub called the **frontoparietal network** (FPN) which is the most densely connected to all other brain hubs, playing the central role in control and communication. (7)

Summary

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So now you have an understanding of IQ in terms of *g* and IQ tests from a scientific perspective within the IQ testing tradition. From figuring out the IQ problems above, you now also have a feel for what kind of processing the frontoparietal network of your brain is doing when you exercise *g*.

What You Have Learned In This Unit

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You have learned the following in this Unit. Mentally check them off if you understand them. If any of them are unclear you can go back and review.

- That IQ tests are constructed to measure *g*
- That *g* is the general intelligence factor underlying the 'positive manifold' of all cognitive abilities
- That *g* overlaps with 9 or more (second level) 'multiple intelligence' subfactors AKA broad cognitive abilities
- That the subfactor with the highest overlap with general intelligence is fluid intelligence (Gf)
- What fluid intelligence is: our reasoning, inference-making and pattern finding ability
- That full-scale IQ tests measure a number of the broad cognitive abilities and (via those) an overall estimate of *g*
- That culture-fair IQ tests measure fluid intelligence as an estimate of *g*
- What working memory (Gwm) is: our mental workspace with a limited 'bandwidth' or capacity
- That working memory and fluid intelligence are highly related and intelligence (Gf) and working memory (Gwm) operate together as kind of 'central processor' and 'bottleneck' in our information processing
- That our Gwm-Gf central processor (*g*) has a neural basis in the fronto-parietal network that that acts as a flexbile hub in the brain's circuitry.

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(6) Jung, R. & Haier, R. (2007). The Parieto-Frontal Integration Theory (P-FIT) of intelligence: Converging neuroimaging evidence. The Behavioral and brain sciences. 30. 135-54

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Fluid Intelligence: Fast & Slow

Unit 2

From Unit 1 you will now have a better mental model of what IQ *is* and how it's tested.

A quick recap...

Your IQ is a measure of ***g*** - the general intelligence factor - that explains the positive manifold (positive correlations) found to underlie performance on diverse cognitive tasks. The brain-basis of *g* is the **frontoparietal network** (FPN).

By statistically analysing test scores, the *g* factor can be further split into a number of subfactors or broad abilities.

Some of these broad abilities overlap/correlate more with *g* than others. The one with the most overlap is **fluid intelligence** (or fluid reasoning). It overlaps so much it can be considered as a proxy for *g* itself.

Stand-alone fluid reasoning tests such as Raven's Advanced Progressive Matrices can give you an accurate measure of your IQ. If you take an IQ-based career aptitude test, chances are you'll just get a reasoning test for fluid intelligence.

Fluid Intelligence (Gf):

The ability to reason, infer relations and spot patterns on problems that draw on minimal prior knowledge and expertise.

Our fluid intelligence (Gf) is short-hand for the neural circuitry we use to find solutions, figure out or grasp abstract relationships, concepts and rules, reach conclusions, and generate new knowledge or actions, from the information we're attending to in working memory.

Gf is an **inference engine**. It generates inferences through either **induction** (rule induction) or **deduction** (rule application).

Induction:

The ability to observe data and discover the underlying principles, patterns or rules that organize it or determine its behavior. This ability includes rule inference.

Induction can also occur in complex perception - for example, when expert chess players 'see' a pattern in the configuration of pieces that others cannot see.

Deductive/Sequential Reasoning:

The ability to reason logically or sequentially using known premises and principles This ability also is known as rule application.

Sequential reasoning also occurs in planned actions, where - for example - musicians may improvise music, following rules of composition.

Gf is a **mental modeling system** that evolved in the hominin line to flexibly infer new understanding, knowledge and solutions, and learn and apply rules. Gf depends on deliberate, attention-focused cognition in **working memory** to solve on-the-spot problems that cannot be solved on 'automatic pilot' by using previously learned habits, schemas, and scripts.

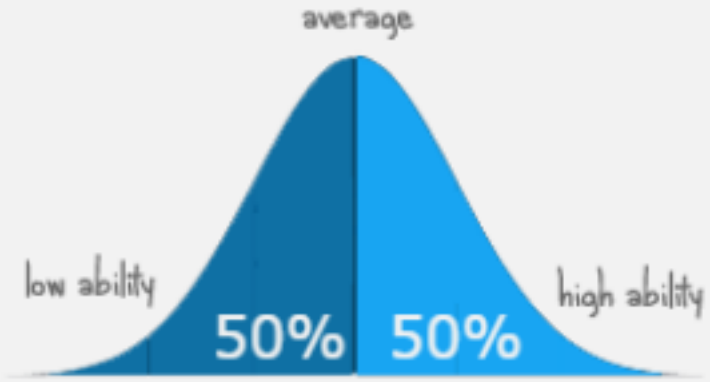
Once you can solve a problem, comprehend something or execute a complex action, automatically through hard-wired long-term memory, then you 'offload' your information processing from fluid intelligence to **crystallized intelligence**. We'll look at crystallized intelligence in the next Unit.

WM-Gf LINK

We also learned in Unit 1 that **working memory** (Gwm or WM) and fluid intelligence are highly related: WM test scores can be very good predictors of Gf culture fair IQ test scores.

Working Memory (WM or Gwm):
The ability to hold and manipulate information 'in mind', over brief intervals: our 'mental workspace'. It's capacity is limited—we can keep only a certain amount of information in mind at any one time.

Our working memory depends on **attention control** - our ability to focus on what is needed while shielding from distraction or flexibly shift our focus. Together, WM and attention control are called **executive functions** (or EFs).



Both fluid intelligence and working memory have normal (bell shaped) distributions in the general population like this one shown here - just like overall IQ (*g*) does.

Some people with high ability reason/infer much better or have much better working memory capacity

than others. But most people fall closer to the average. This is called the **bell curve** of IQ.

In Unit 1 we saw how our working memory's mental workspace functions as an **information processing bottleneck** for our overall inference power. This is a limiting factor on our intelligence.

We saw that the more information that can be processed through this bottleneck, the more overall capacity we have and the smarter we are. Have you experienced times when you've lost track of useful information that you had previously been attending to while trying to figure something out? That's this bottleneck at work. We all differ in the **capacity** of our WM bottleneck.

This is an explanation for the relationship between working memory and fluid intelligence. But there's more to this story.

Fast vs Slow Intelligence

It turns out the relationship between working memory and fluid intelligence isn't always strong. (1)

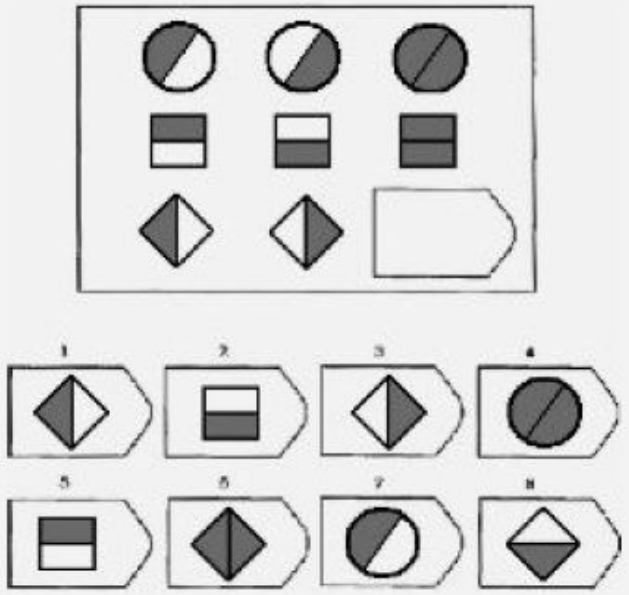
Adam Chuderski conducted a study back in 2013 that sheds light on this. (2) He reviewed 26 studies that recorded both working memory scores and the Raven's Progressive Matrices test scores - the most widely used measure of fluid intelligence.

He found that the studies that increased the time limit of the fluid intelligence tests significantly increased the correlation between WM and Gf.

The overlap was close to 100% for short fluid intelligence tests, but dropped to under 40% for untimed, longer tests. For these longer tests, WM contributed much less to Gf.

He found the results intriguing. Follow-up studies revealed one of the reasons why. With speeded tests, the kinds of patterns that need to be spotted are much simpler, requiring less in-depth reasoning and processing power, as in the really easy example shown here. In this case, IQ tests are essentially tests of working memory.

The kind of reasoning tested here (and remember, this is a really easy example of the kind of reasoning involved) is called **fast intelligence**.

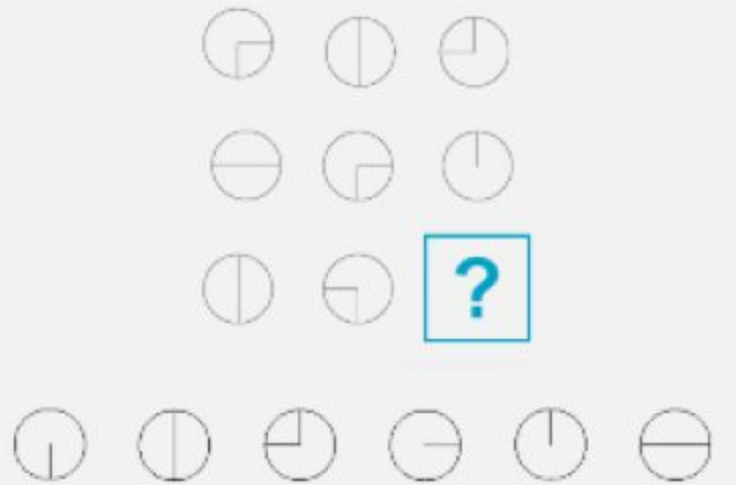


Untimed matrices tests get more difficult as they progress, and they include questions needing more complex and in-depth reasoning. These more

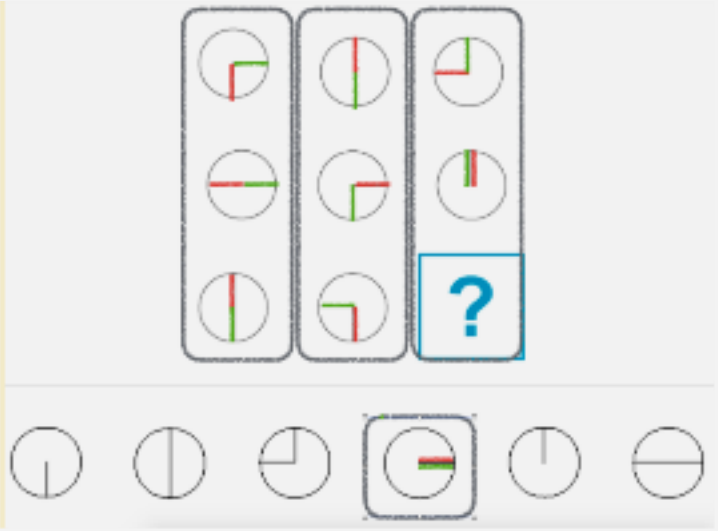
complex problems require not only WM but also the search and retrieval of relevant knowledge, problem-solving strategies, as well as relational or associative abstraction/rule discovery involving

encoding & learning. (2) We will visit this claim again in Unit 3.

The kind of reasoning tested here is called **slow intelligence**.



There's no immediately obvious pattern or progression. To solve it, requires using strategies to recode the line into 2 segments and have the insight that those segments can overlap - as shown here.



So now we can talk about two types of intelligence measured by IQ tests: **fast** vs **slow**.

Each has different strengths and weaknesses.

In terms of how fast vs slow intelligence play out in our lives, Adam Chuderski explains it like this (2):

> [fast intelligence is] the ability to cope with complexity in a dynamic environment, thus having a high real-world validity, as the technological and informational pressure of the world increases rapidly, but it may underestimate people who regardless of their limited capacity would work out good solutions in less dynamic environments. [Slow intelligence is] a more comprehensive...reasoning ability, including the contribution of intellectual faculties that lay beyond WM, and seem to be complementary to it.
>
> — Adam Chuderski

Summary

Now you should have a better sense of your fluid intelligence (and by implication your general intelligence) as an **inference engine**. It is an inference engine for both **inferring** new rules and knowledge, and applying new rules systematically, in order to generate new knowledge or achieve problem solving goals. You should also have an understanding of how intelligence can be either **fast** or **slow**.

What You Have Learned In This Unit

You have learned the following in this Unit.

Mentally check them off if you understand them. If any of them are unclear you can go back and review.

- That fluid intelligence (Gf) is an inference engine that processes either inductively or sequentially/deductively.
- That working memory's mental workspace functions as an information processing bottleneck for our overall inference power and that we all differ in the capacity of this bottleneck.
- That the bottleneck is a key limiting factor on our intelligence.
- There are two types of intelligence: fast and slow.
- That fast intelligence depends more exclusively on working memory ability.
- That slow intelligence depends on both working memory, retrieval fluency and learning/encoding ability.

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Fluid & Crystallized Intelligence

Unit 3

Fluid & Crystallized Intelligence

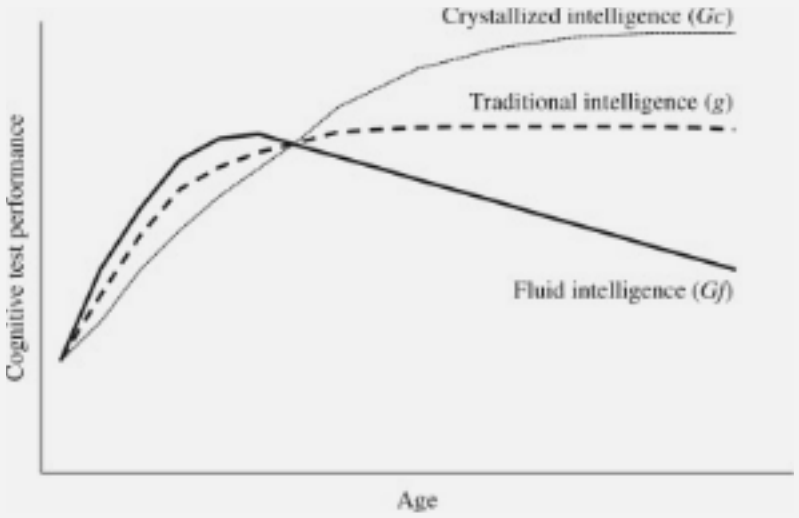
The theory of fluid and crystallized intelligence, as originally proposed by the psychologist Raymond Cattell back in the 70s (1), understands intelligence as the interplay of two complementary abilities: fluid & crystallized intelligence. While fluid intelligence (Gf) is our ability to reason, abstract and make inferences, crystallized intelligence (Gc) is the ability to store and structure knowledge and skills in long-term memory.

Long term memory

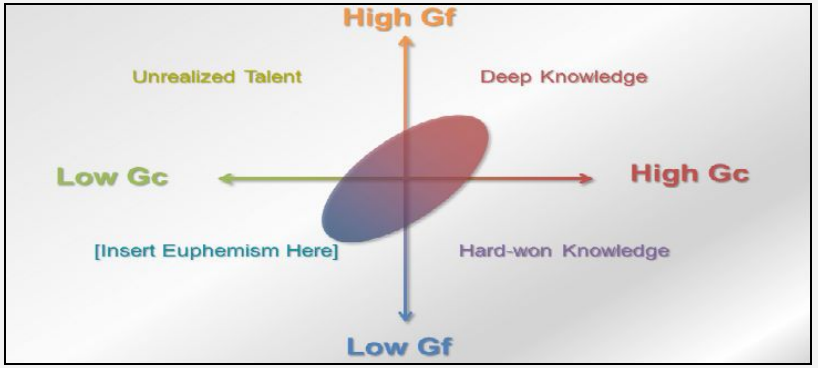
Compared to working memory, this has a much larger storage capacity. The information it holds is more durable and stable. Long-term memories can contain information about episodes in a person's life, semantics or knowledge as well as more implicit types of information such as how to use objects or move the body in certain ways (motor skills).

opportunities we have as we shall see below.

Gc is a broad ability that independently accounts for a variety of outcomes (such as specialist skills) and is often the superior predictor than Gf. Gc may increase in importance throughout adulthood when compared to Gf. (2)



Gc - our knowledge base - is the *product* of mainly Gf but also other factors, including the education and

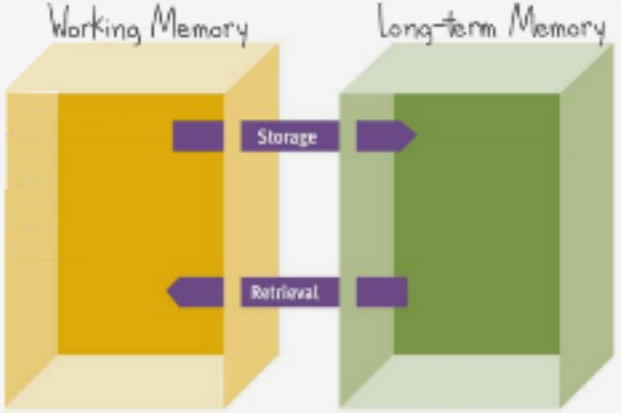


The **investment** of Gf into strategies and activities that impart knowledge entwines Gf and Gc in a two-way relationship that unfolds over time. The action of Gf in the past is largely responsible for present Gc. As Cattell puts it, "*... this year's crystallized ability level is a function of last year's fluid ability level—and last year's interest in school work.*" (3)

Learning & Retrieval

- - - - x

It is known that the **ability to learn** (encode/store) and the **efficiency of retrieving** knowledge from Gc are two essential components underlying fluid intelligence (Gf) in addition to **working memory**. Encoding and retrieving from long-term memory predict fluid intelligence over and above working memory. (4)

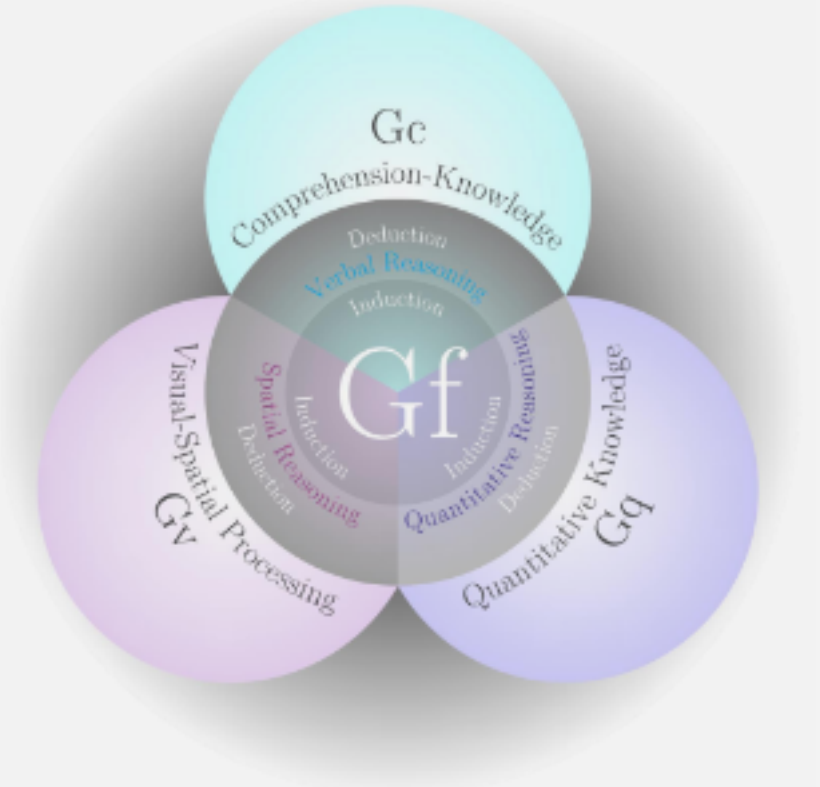


> Intelligence is not the amount of information people know, but their ability to recognize, acquire, organize, update, select, and apply it effectively.
>
> -Gottfredson, 1997, p. 93

So the CPU (central processing unit) of fluid intelligence is the combination of WM and learning & retrieval fluency from long-term memory knowledge stores.

The crystallized intelligence (Gc) from which WM retrieves information can be partitioned in different ways based on the **content** of Gc. Here are three types of content that **fluid intelligence** works with: (5)

1) The ability to make use of **mental imagery** to solve problems -discriminating & transforming images in the mind's eye (Gf-Gv).
2) The ability to make use of **verbal** or **language-based knowledge** to solve problems (Gf-Gc)[1].
3) The ability to reason with **quantities**, **mathematical relations** and operators (Gf-Gq).



3 crystallized modalities of fluid intelligence

[1] Note that in this diagram 'Gc' is 'comprehension-knowledge, not crystallized intelligence as it is more conventionally used.

Fluid intelligence is typically tested in IQ tests - whether culture fair or full-scale - through one of three crystallized intelligence modalities shown in this figure.

In principle Gc can be fractionated further into other knowledge-areas than just visuospatial, verbal, and quantitative[2]. These include psychomotor skill, reading-writing ability (literacy), emotional intelligence and social intelligence.

And fluid intelligence can encode and retrieve from each of these crystallized knowledge domains and draw inferences within them.

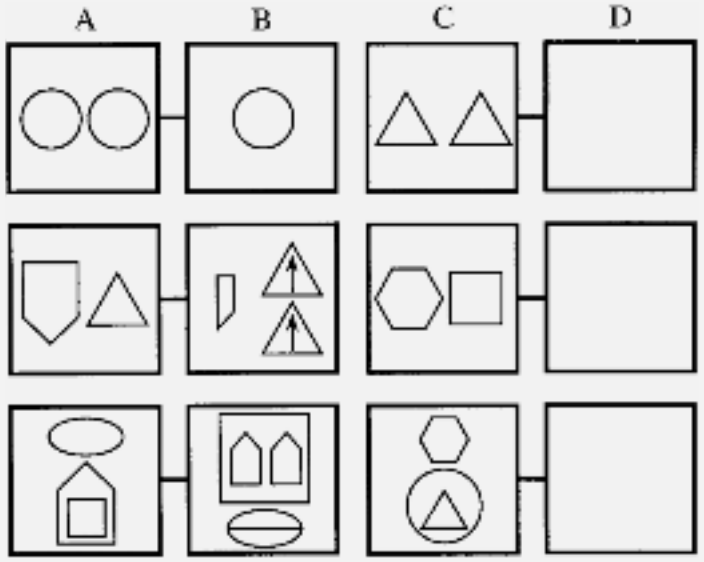
Psychomotor 'inference' at work in BJJ

Analogical Reasoning

Our ability to reason with **analogies** - between and across modalities - is another way of testing fluid intelligence.

[2] This idea is developed by Kovacs and Conway's Process Overlap Theory (6)

Analogical reasoning is the ability to find relations between structures and to explain new concepts in terms of familiar ones. Analogical reasoning ability can be modality-specific (as shown below) but it can also be cross-modal, where e.g. real world situations can be related to e.g. shapes.



Analogical reasoning ability is closely linked to domain-general fluid intelligence and solving analogical problems depends critically on the 'flexible-hub' fronto- parietal network (FPN) of our intelligence. Individuals with high fluid intelligence perform well on analogical reasoning tasks. (7)

The Co-Evolution of Fluid & Crystallized Intelligence

It's easy to see how with deeper immersion in different areas of knowledge and expertise, that learning-retrieval abilities to *"recognize, acquire, organize, update, select and apply"* will improve in a **positive feedback loop** that magnifies both G*f* and G*c* (and overall IQ) together.

For an obvious example, as you follow a college curriculum, your experience and knowledge over hundreds of hours of comprehension and problem solving will enable you to recognize new patterns, make better inferences, and reason more effectively.

More generally, it's not only the case that "*... this year's crystallized ability level is a function of last year's fluid ability level.*" It's also the case that "*...this years fluid ability is a function of last years crystallized ability.*"

This is confirmed by the **Flynn effect** that shows that in most countries around the world there has been a 3-5 point IQ increase each decade since back in the earlier part of the 20th Century. (8) This is largely due to education: each passing school year can augment a child's IQ level by several points, and that simply going to college vs leaving formal education at high school can result in as much as a 20 point IQ difference. (9)

So we can see how with more learning and larger crystallized knowledge stores, your fluid reasoning can be augmented which in turn improves learning & knowledge in a positive feedback loop.

And what about the important link with your working memory (WM)?

WM-Gf-Gc Mechanics

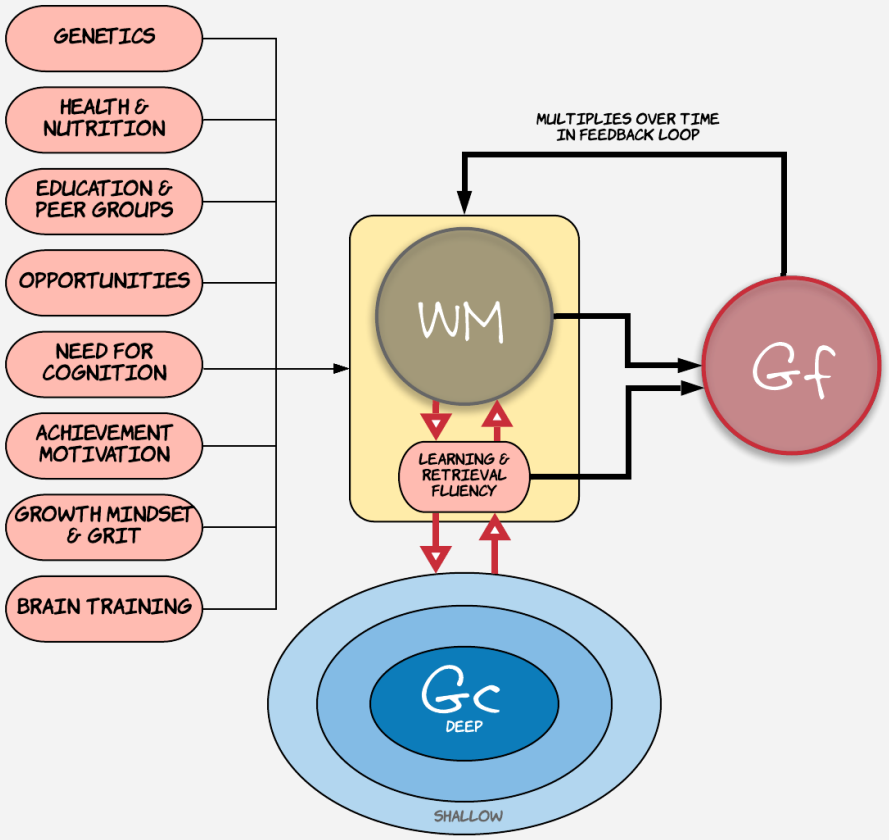
When there is a large overlap of working memory and fluid intelligence. the cognitive challenges you face are relatively simple, needing quick adaptive responses - often in quickly evolving situations. Imagine multi-tasking in a dynamic work environment. The kind of pattern spotting & reasoning you do here are general-purpose and relatively simple and 'off the cuff'. There are minimal demands on learning, search and retrieval from crystallized intelligence.

Here we're in the territory of **fast intelligence** as we saw in Unit 2. This accounts for much of our day to day intelligence.

But you will also find yourself in more reasoning & inference intense situations requiring more processing power - when you have a really hard problem to solve, a highly challenging & complex task to accomplish, or something difficult to learn.

Now we're in the territory of **slow intelligence** and you will need to engage more fluent encoding & retrieval from long-term memory, and also tap potentially deeper or more extensive regions of your crystallized knowledge stores.

This is shown below in the WM-Gf-Gc Model of intelligence that shows how fluid and crystallized intelligence work together.



THE WM-GF-GC MODEL OF INTELLIGENCE. MARK ASHTON SMITH (2019)
WM = WORKING MEMORY; GF = FLUID INTELLIGENCE; GC = CRYSTALLIZED INTELLIGENCE

Both your working memory (WM) and your learning & retrieval fluency ability (Glr) contribute independently to your fluid intelligence (Gf).

The more you need to actively engage Glr to access crystallized intelligence when solving problems or comprehending information, the more you engage **slow intelligence**. The less you need to do this, the more you engage **fast intelligence** - and pure WM.

What this model above tells us is that positive **feedback cycles** play and important role in the evolution of fluid and crystallized intelligence over time. A number of factors shown in the model (genetics, health & nutrition, education, opportunities, etc) have a life-long impact on the 'central processing unit' of WM and Glr - and thus the evolution of both fluid and crystallized intelligence.

For example, the better your education, and the more achievement motivation you have, the more you can effectively apply your WM and Glr to understanding the world around you.

In this positive learning process, you both expand your crystallized intelligence **and** improve your Glr (which depends on the depth of your knowledge) - which in turn augments your fluid intelligence!

With more fluid intelligence, you can better apply your WM and Glr, and so on in a kind of 'multiplier effect'. Multiplier effects can be initiated at any point in life, and we will discuss them in more depth in Unit 4.

A Formula For IQ

We're now in a position to capture some of what you've learned in a general formula for intelligence and IQ. Here it is:

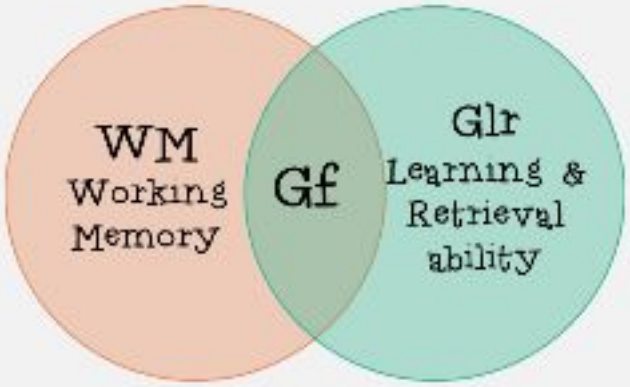
$$Gf = (WM \cap Glr)$$

$$Gc = \sum_{i=1}^{n} Gc_i$$

$$g = (Gf \cup Gc)$$

$$IQ = g$$

Fluid intelligence (Gf) is the intersection of **working memory** (WM) and **learning-retrieval ability** (Glr) from relevant knowledge in **long-term memory** (crystallized in. 'Learning-retrieval' is also called 'encoding-retrieval': it is our ability to encode our reasoning and pattern finding in working memory into long-term memory, and retrieve that information again from long-term storage. Gf is the interaction/intersection of these two constructs.



Glr plays a more important role in slow intelligence, while WM plays the more important role in fast intelligence (see Unit 2).

Crystallized intelligence (Gc) is the union of all the different specialist domains of knowledge (such as visual spatial, quantitative and verbal).

General intelligence (*g*) is the union of fluid (Gf) and crystallized (Gc) intelligence.

IQ is a measure of general intelligence.

Summary

In this Unit we have gone beyond definitions and distinctions and built up a more mechanistic model of how intelligence actually works and evolves over time. In the following Unit we'll see detailed evidence for this dynamic process.

What You Have Learned In This Unit

You have learned the following. Mentally check them off if you understand them. As always, if any of them are unclear you can go back and review.

- That the CPU (central processing unit) of fluid intelligence is the intersection of WM and learning & retrieval fluency.
- That general intelligence can be understood as a duality of fluid (Gf) or crystallized (Gc) intelligence - our knowledge store.

- That crystallized intelligence fractionates into specialized (domain specific) knowledge areas such as verbal, visuospatial and quantitative, but also psychomotor, emotional and social.
- That both working memory (WM) and encoding/retrieval ability (Glr) determine fluid intelligence ability
- That the WM-Glr 'processing unit' acts as a domain-general **hub** interacting with the Gc specialist knowledge domains. (This is the fronto-parietal hub network.)
- The Gf-Gc interaction via working memory and Glr accounts for the co-evolution of intelligence over the lifespan.
- That impact factors such as education and opportunities - as well as genetics - shape this co-evolution process.
- That intelligence (*g*) can be captured in a simple, condensed formula:

$$Gf = (WM \cap Glr)$$

$$Gc = \sum_{i=1}^{n} Gc_i$$

$$g = (Gf \cup Gc)$$

$$IQ = g$$

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20 Points Plus Malleability of IQ

Unit 4

Jordan Peterson: IQ Determinism

I'll start this Unit by looking at Jordan Peterson's deterministic views on IQ.

Peterson is a professor of psychology at the University of Toronto, Canada. He's an avid YouTuber, and you need to keep in mind the following: Peterson has become a public intellectual. He adopts polemical positions. He has made his mind up about many contested issues and runs with his convictions in a way that engages audiences.

The contentious video below presents Peterson's deterministic views of the nature of intelligence and the role it plays in the workplace.

There's a lot that can be constructively criticized in his bold claims. But any of the concepts he touches on are well-established, and it's valuable to put such a position in the public domain clearly and forcefully for the purpose of stimulating reflection and debate.

And Peterson succeeds in this! The video has 1640 comments as of 30th Oct 2018! Here are the first of these when I first viewed it:

"I have an IQ of 100 even. I'm perfectly average yet I manage over 30 people, a lot of them are smarter than me. He's not considering factors such as soft skills, leadership, fearlessness, work ethic and attitude."

Here's the video (1) - see what you think.

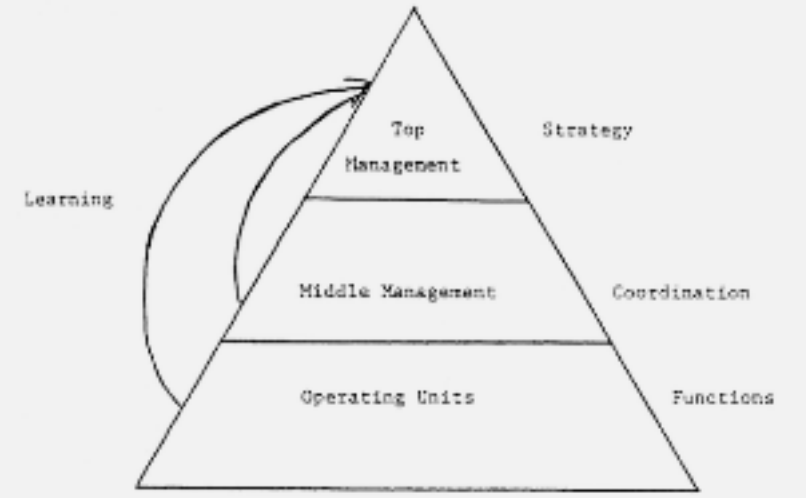
Here are some quotes from the video - grouping quotes into topics.

Later in this chapter I will be challenging some of these views - based on solid evidence that Peterson does not incorporate in his thinking on this.

Fluid Intelligence In The Workplace

"You've got to know there are differences in intelligence. It's really important."

"...as you climb hierarchies of competence, the demand on fluid intelligence increases"



Competence Hierarchies

"Almost all jobs that are at the top of complex dominance hierarchies require very high intelligence, insane levels of conscientiousness, as well - generally speaking - pretty damn high levels of stress tolerance."

"As you move down the hierarchy, the jobs get simpler, they're more likely to be assigned by other people, or they're repetitive....People with lower IQs are more suited to more repetitive jobs. "

"If you want to be the best at what you are doing, bar none, then having an IQ of above 145 is a necessity and maybe you're pushing 160 in some situations...that's making you 1 person in 10,000 or even 1 person in 100,000."

Intelligence As Speed

“Why is it that smart people are at the top of dominance hierarchies? And the answer to that, in part, is that they get there first. Right? I mean everything is a race, roughly speaking, and the faster you are the more likely you are to be at the forefront of the pack. Intelligence in large part is speed."

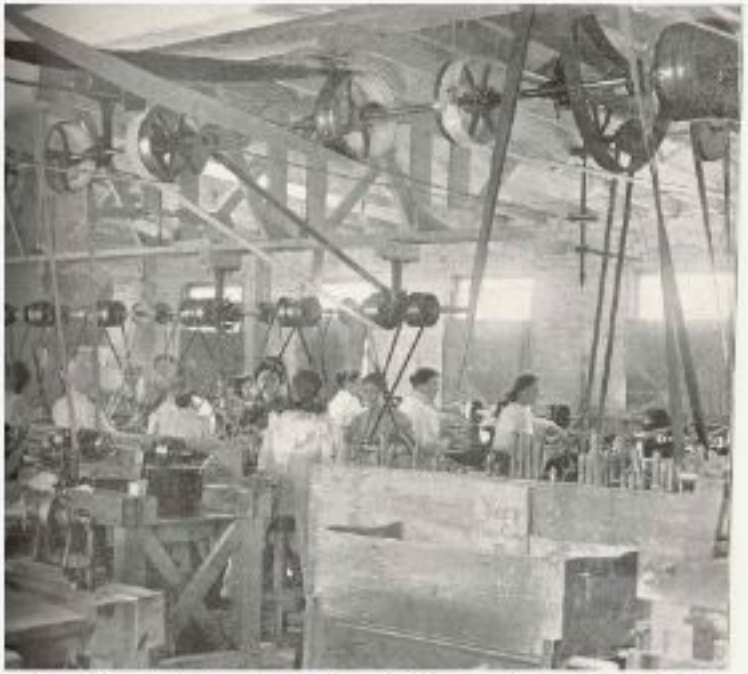
Being The Wrong Brain For The Job

"If you go into a job, and you're not smart enough for that job, you're going to have one bloody miserable time".

"You don't want to be the stupidest guy in the room. It's a bloody rough place to be. And you

probably don't want to be the smartest guy in the room either because what that probably means is that you should be in a different room.... If you're right at the top, you've mastered it. It's time to go somewhere a little lower so you've got something to climb up for."

"most people have at least one significant weakness in their intelligence-personality makeup and you've got to be careful not to place yourself in a position where that is going to be a fatal flaw".



Drilling holes in buttons in the Mussel Fishery and Pearl-Button Industry

Being The Right Brain For The Job

"what you want to do if you want to maximize your chances of both success and...well-being is you want to find a strata of occupation in which you would have an intelligence that would put you in the upper quartile. That's perfect. Then you're a big fish in a small pond."

Peterson tells his students in the lecture that there is nothing they can do to change their IQs.

Is IQ so genetically predetermined and stable across time, as Peterson assumes?

Where Peterson Goes Wrong

Peterson is right on a number of scores - particularly regarding his insight that 'cognitive capital' is now an important feature of our economy, and individuals with high IQs contribute substantially to national GDPs.

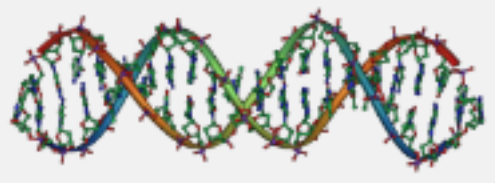
But Peterson is overly deterministic about IQ. He believes that you have a fixed IQ and that there's nothing you can do to improve it. His claim is that you need to find the right job for your IQ level in terms of complexity and level in the 'hierarchy of competence' - or you will be out of your depth and miserable. The evidence presented in this Unit should convince you that this view is very mistaken.

Let's look at each item of evidence in turn.

1. G Is Not Found In Our Genes

Studies have not identified any specific set of genes that underlie the genetic basis of differences in *g*. As concluded in this comprehensive 2015 review on the genetics of intelligence (2):

"identifying specific DNA variants that contribute to the high heritability of intelligence....will be a difficult task.... heritability of intelligence is caused by thousands of DNA variants, many of these effects are likely to be infinitesimal or even idiosyncratic."



The key evidence that IQ is fixed in stone and cannot be changed comes from (a) the research showing a high heritability of IQ - i.e. the high genetic contribution to differences in IQ scores (2); and (b) research showing the high stability of individual IQ scores in adulthood - i.e. IQ scores don't tend to change much from early through to late adulthood. (3)

2. IQ Stability? - Not So Much

A high impact article was published in the journal *Nature* in 2011: *Verbal and non-verbal intelligence changes in the teenage brain*. (4) Cathy Price at University College London and her colleagues tracked the IQs of 33 adolescents between 12- to 16-years-old for four years. Fluctuations in IQ were enormous: 20-plus IQ points, one way or another - enough to take a person of 'average' intelligence to 'gifted' status, or vice versa. These changes in

students' IQ were associated with structural and functional changes in the students' brains.

OK - so we're looking at children here. They have highly plastic brains.

But there is also good evidence that IQ in adulthood is not stable. An international 2012 study by Clouston and colleagues (5) demonstrated *"a university education had a robust impact on adult fluid [intelligence] even after adjusting for adolescent cognition in multiple domains."*

This study reveals that a person with average adolescent cognition who earns a university degree can expect similar adult fluid intelligence as someone with adolescent cognition measuring **8 to 23 IQ points** higher who did not go to university. So just by virtue of taking his classes and getting a university degree, Peterson's students may gain an additional 20 IQ points!

What about after college level?

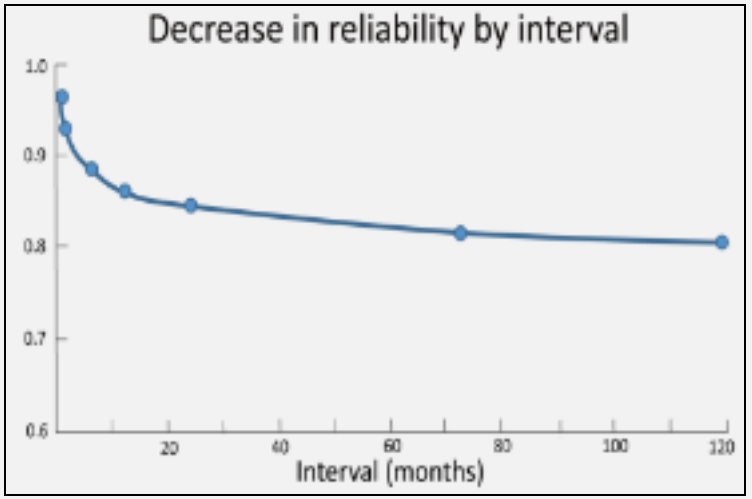
Direct studies of intensive postgraduate education have not been conducted. They need to be, because it can be expected that dramatic IQ changes would also occur for adults who pursue 4-5 year post-graduate

degrees such as Ph.Ds into their late 20s - or mature students who pursue higher education degrees later down the line.

Why should we believe this?

First reason. By reviewing a number of studies in the literature, Schuerger and Witt (6) found that in 13% of the 6-years-old scores changed 15 points or more when tested in adulthood. The same was true in 7% of 30-years-old. If IQ became static by adulthood 1 in 14 thirty-year-olds would not see a 15 point plus change in their IQs over the following years.

Second reason. The stability (correlation) of IQ scores changes dramatically as a function of the interval between IQ test taking: the longer the interval between two intelligence measurements the greater the instability (6). Test-retest reliability data was gathered from 34 separate studies on common IQ tests (the Stanford-Binet, the WISC, the WISC-R, the WAIS, and the WAIS-R) and there was a drop in reliability from around 0.95 when tested within a month to closer to 0.80 when tested 100 months (8 years) later. (6) This level of correlation means that around 35% of the differences in IQ scores from 1 test to the other in the sample of test takers were not explained by a stable underlying IQ.



Third reason. There has been a **15-20 point IQ increase** in entire adult populations in many countries over the course of just a couple of generations between 1950-1990. This has nothing to do with changing DNA - as explained in my discussion of the Flynn Effect that we review below.

Fourth reason. There is growing support among experts for a dynamic understanding of IQ, requiring us “to identify full developmental trajectories, to assess how genes, brain, cognition, and environment interact with each other” to “better explain why intelligence can rise or fall over development” over the entire lifespan from birth to old age. (7)

University of Pennsylvania psychologist Scott Kaufman - 2011-2012 recipient of the Mensa International Award for Excellence in Research - is a proponent of the dynamic view. In his highly influential book *Ungifted: Intelligence Redefined* (8) a key assumption is that abilities underlying intelligence are not static entities but are constantly changing throughout the life-span. Kaufman views intelligence as the dynamic interplay of engagement and ability over time in the pursuit of personal goals.

Dynamic IQ Hypothesis

The IQ levels typically stabilize in early adulthood in comparison with childhood only because we leave the intense and more generalist educational environments of school or university and find relatively stable cognitive niches’ for ourselves in terms of cognitive training and activity.

3. High Heritability? Not So Much

Heritability estimates the degree of variation in IQ scores in a population due to genetic differences (the DNA you inherit from your parents) compared to environmental differences (such as cultural attitudes, resources, health care schooling, exercise, nutrition, brain training, and so on). By young adulthood (20 years old) heritability of IQ is typically estimated at around 60-80% where it stabilizes. (2)

Heritability estimates underlying the claim that genes are firmly in control of IQ by adulthood, and that environmental impact (with an impact of only 30%) is relatively marginal. This evidence is the basis of Peterson's claims that you better not end up being mismatched with a higher level in the 'complex dominance hierarchy' and "people with lower IQs are more suited to more repetitive jobs."

But let's look at heritability more closely.

The Flynn Effect

If our genes are in control, average national IQ levels should not change dramatically over one or two generations since genetic makeup takes . But they have done - dramatically.

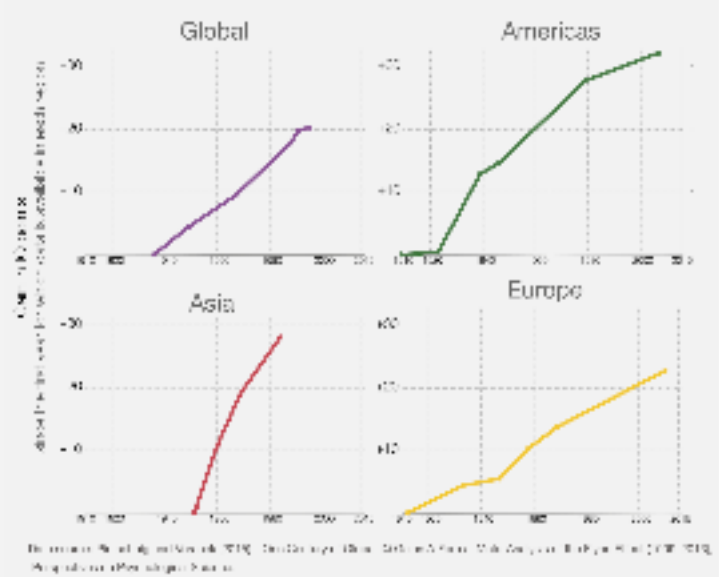
For an example, 18-year-old Dutch men tested in 1982 scored 20 IQ points higher on the same fluid intelligence tests than did 18-year-old Dutch men in 1952. the average Dutch IQ between 1952 and 1982 has increased 20 IQ points.

This is the well-known and much-discussed Flynn Effect. (9)

To see just how dramatic this effect is, have a look at the meta-analysis data opposite from a comprehensive study looking at 271 independent studies comprising four million participants covering a time span of 105 years (1909–2013). Gains of

20-30 IQ points. Across the globe there has been close to a ½ point annual increase in national fluid intelligence since 1909, and the gains are stronger for adults in a country than children. (10)

Genetic explanations - such as different reproductive patterns (e.g. out-breeding, finding more genetically diverse mates, natural selection, etc) - can be ruled out here. The primary cause of this large, average IQ increase is environmental, not genetic. (10, 11)



So what is going on? How can the paradox of high heritability of IQ with a dramatic environmental impact on IQ be resolved?

Masking The Environment

The answer lies in the way that heritability is calculated; it actually masks the true impact of the environment. For argument's sake, let's look at pairs of identical twins raised in different environments (e.g. through adoption) to estimate the relative contribution of genes and environment to their IQ levels at 20 years of age.

If genetic influence was 100% we'd not expect any difference in IQ levels between the pairs, no matter how different their environments since their genes are identical. If environmental influence was large, we'd expect quite a bit of variation in pairs of IQ scores. Let's say we find that there is some variation in pairs of scores but not much, and that we estimate

that 75% of the variance in their IQ scores was due to genetics. Sounds like genes are in control right?

Wrong. In reality environment has much more impact than the remaining 25%. This is because there is a hidden **two-way causation** between the twins' cognitive abilities and their environments. Higher IQ twins will generally be in more enriched, cognitively stimulating environments (e.g. stimulating friendship groups, supportive cultural attitudes, positive educational environments and so on) largely because of initial genetic differences that led them to those environments.

Over time environments are 'sculpted' by our choices to match our cognitive abilities, and more stimulating environments in turn increase those cognitive abilities.

> A higher IQ leads one into better environments causing still higher IQ, and so on. People who are born with a genetic advantage are likely to enjoy an environmental advantage as a result.
>
> -Dickens & Flynn, 2001

In summary, the way heritability is measured assumes that environments are random and independent of cognitive ability. In the case of the twins, it's assumed that once twins are separated at birth and raised by different households that their environments are independent from their shared genes. But their shared genes actually shape both of their environments (social, activities, school routines, etc) to make them similar and correlated. And the more this happens, the more the heritability statistic masks the true impact of environment. (11)

Multiplier Effects & Feedback Loops

And there's more to this masking story. It's what's called the **multiplier effect** and it's analogous to the so-called 'law of attraction'. (11)

Small initial differences in IQ (e.g. 2-5 IQ points) **or** favourable environments (a good mentor, an education-valuing family) can magnify quickly over time through ongoing IQ-environment feedback loops into very large IQ differences.

> "[A] genetic advantage may itself be rather small. However, through the interplay between ability and environment, the advantage can evolve into something far more potent. So we have found something that acts as a multiplier."
>
> -Dickens & Flynn, 2001

The same multiplier effects happen in sports. A child with minor genetic or environmental advantages for playing basketball, to use Dickens and Flynn's example, may end up in a genetics-environment cascade over the years of mutually reinforcing advantage that can turn someone average into someone at the top of their game.

The same process works with IQ and the trajectory can take a steep upward turn over just a matter of a years. A well resourced, educated, middle class family may provide a small environment-IQ advantage for their preschool child with a fairly average IQ, and this process may take that child down an IQ amplifying path to a giftedness program and Harvard, coming out the end with a high cognitive ability and an IQ score of 135.

The process we're describing here is a positive feedback loop. It is a good, scientifically based example of 'vectorizing IQ'.

Note that it could also be a downward-spiraling vicious cycle. Initially minor losses of opportunity or genetic disadvantages can amplify considerably over time. The Harvard student's pre-school buddy who started off as a toddler just 5-10 IQ points less smart may, through cultural/family values, personal attitudes, streaming, labelling, and so on, end up as a factory Assembler - at that level in Peterson's hierarchy of competence, with an IQ of 80.

What Can Help Multiplier Effects?

All these factors have been proposed with supporting evidence in the scientific literature: (10)

1. Better **education**. Since 1909 the quality and number of years in education has increased. Flynn effects are considerable for crystallized intelligence - our culture-rich language ability and knowledge in long-term memory.

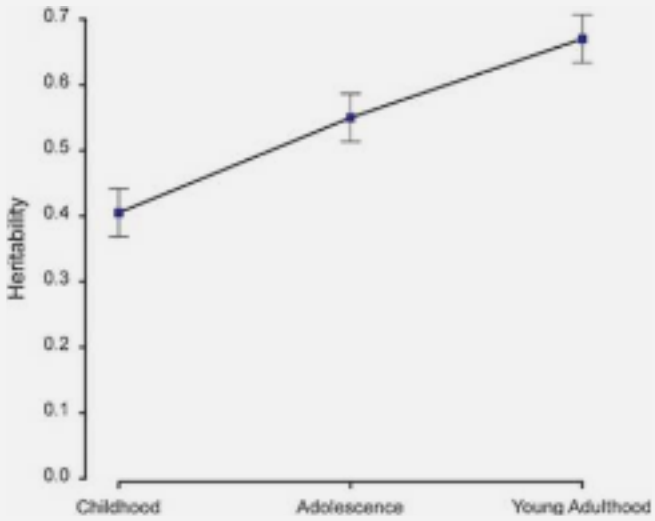
2. Increases in **technology**. Our constant exposure to modern appliances and complex, information-processing devices incidentally train analytical and fluid reasoning abilities. The strongest Flynn effects are seen with fluid intelligence and there are periods of acceleration in Europe and the US during e.g. the 50s when technologies became more widely available and computers were invented.

3. Better **nutrition** and less **pathogen stress**. Poor nutrition and pathogen stress has been shown to be associated with low IQ test performance in numerous countries, particularly Gf. Brain development in children demands a large percentage of the metabolic turnover (close to 90% in newborns and 34% at age 10) - an energy demand that needs to be met to ensure cerebral development.

4. **Socioeconomics & life history speed**. Slow life history individuals have fewer lifetime sexual partners, fewer offspring, and later parenthood, as compared with fast life history individuals. Different environmental conditions may favor either slower or faster life history speed. In lower socioeconomic conditions, with more adverse conditions, there is less investment in cognitive ability maturation and differentiation; effort is funnelled into basic survival needs.

4. The Instability of Heredity

The heritability of intelligence (h^2) increases from about 20% in infancy to perhaps 80% in later adulthood. (2) There is a dramatic increase in heritability through to early adulthood as this study's data shows:



Does this mean that our genes take more control over this time-span - as if IQ-linked genes become expressed more in our brains and behaviour - like the developmentally regulated genes for adolescence? The answer is no: the same genes affect intelligence throughout the lifespan. (2) So what explains the changing heritability of IQ?

The answer proposed independently by the 'founding father' IQ scholars Jensen, Neisser and Flynn (11) is that it results from the increased matching of environment to IQ with age. As we get older gene-environment effects have an increasing impact in shaping our environments - at work, socially and culturally. And from childhood to adolescence, there is a steep drop in the role of shared environmental factors that are imposed externally on us such as family, school or university.

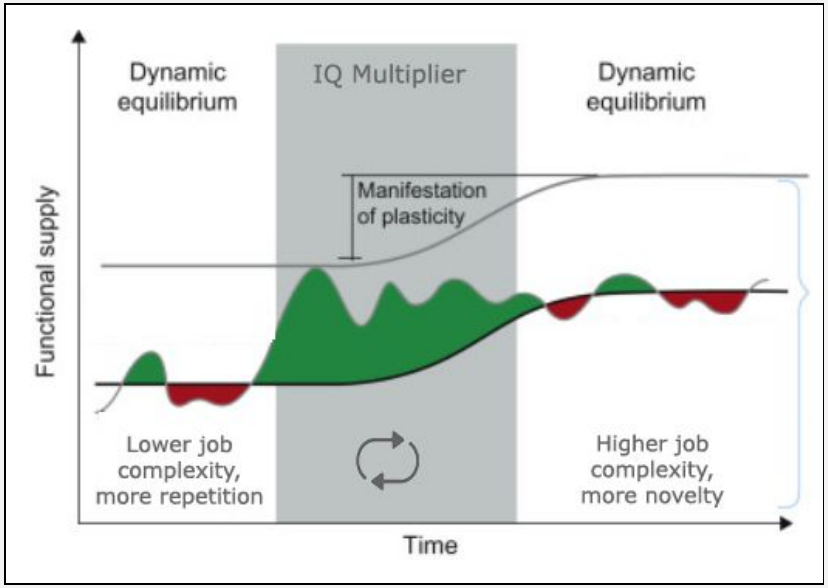
So this doesn't mean that genetics take control of IQ levels in adulthood: it simply means that there is an increasing fit between our environmental 'cognitive niche' and our IQ, just as we find with the multiplier effects.

Summary

In summary, based on the arguments I've reviewed I believe Peterson sends out a fundamentally misleading message. IQ is not genetically fixed. We do not need to 'find our place' in the IQ hierarchy of job complexity and status based on some fixed IQ, not even when we're in middle age, let alone young adulthood.

Let's say you feel like you're not cognitively challenged - or let's say that you work hard to accrue some IQ advantage due to extra job training, educational courses, diet, motivation, brain training, etc. Moving into a new, more complex and varied job may be an excellent way to launch from small advantage in IQ and harness a powerful multiplier effect.

This figure illustrates the adaptive IQ-environment multiplier effect at work. Green represents periods where demands may exceed cognitive ability, when you are not in 'homeostasis', driving plasticity changes and increased IQ.



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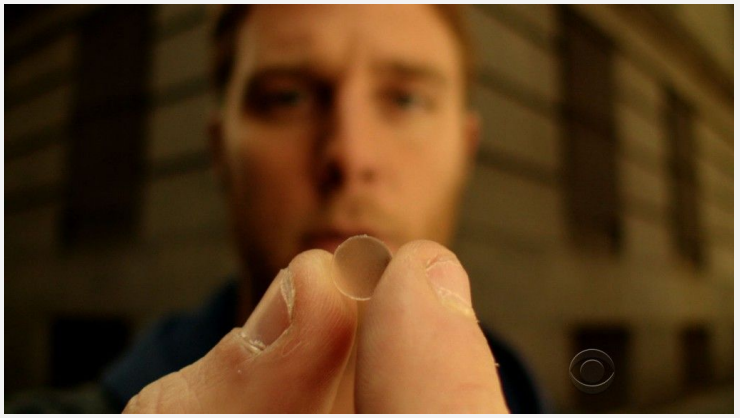
Why & Where IQ Matters

Unit 5

In this Unit we will be looking at the evidence that IQ matters in your life. Review it, follow the references, and decide for yourself how much of a 'magic pill' being smarter can be in life.

Many of you will have seen the movie *Limitless*, directed by Neil Burger. The plot starts as follows: Eddie Morra is a struggling author in New York City. His girlfriend Lindy dumps him, frustrated at his lack of success. After taking the nootropic NZT-48, Eddie's intelligence (*g*) is dramatically augmented and with his new-found powers, he finishes his book, gets Lindy back, improves his entire lifestyle and social circle, and uses his off-the charts IQ to make a fortune investing.



The magic pill (NZT-48) in the movie Limitless

The movie was a success But how much truth is in the idea of the life-changing power of IQ?

Change, Complexity & Choice

Rapid changes in culture and the economy - in careers, technology and lifestyle choices - have made us all aware that we have to be able to learn quickly and be more adaptable than in the past.

The world has become more complex. Think back to 1980. There was no such thing as a personal computer. The Internet and broadband were more than a decade away. AT&T was the only telephone operator in the United States, and the telephone industry was highly regulated. For roughly half of the 4.4 billion people on Earth, virtually no outside communication was possible.

Since 1980, a host of technological and sociological changes have ramped up complexity including:

- Low cost computing power and global IT infrastructure
- Digitization of massive amounts of information
- Ease of communicating rich content globally
- Smart systems (e.g. desktops & phones) that communicate interdependently
- The wholesale rewriting of industry norms and business models
- An increasingly wealthy human population, with more consumer choice, consumption & participation in the formal economy
- Increasing globalization - culturally, economically & politically

> We might think it is easy to adapt, but a little reflection will remind us that our values and dispositions are deeply held and difficult to change. We want security and the thought of change can make us feel very insecure...Yet technology will force on us changes in the way we work and live more quickly than was the case in the past.
>
> — Professor John Heywood, *Learning, Adaptability & Change*

Complexity requires adaptation. A Harvard Business Review article on increasing complexity concludes:

> Complex systems are unforgiving places for companies, and people, who move slowly.
>
> — Rita Gunther McGrath, *The World Is More Complex than It Used to Be*

Illustration: Oscar Bolton Green

From running shoes to dating partners and TV subscriptions to college courses and career choices to sexual identities to lifestyles, we have more choices than ever before. There is so much choice to deal with that it has created a backlash. There are psychologists like Barry Schwartz who argue that while autonomy and freedom of choice are critical to our well-being, too much choice creates anxiety.

And there are now several books and magazines devoted to what is called the "voluntary simplicity" movement. Its core idea is that we have too many choices, too many decisions to make, and we need to simplify and focus on what we really value.

In summary, 20 years into the 21st Century there is a strong pressure to adapt to continual change & increased complexity while managing a proliferation of choices.

So prima facie, **fluid intelligence** sounds a lot like a ‘magic pill’: the world we live in is an ideal niche for fluid intelligence - our capacity to reason and solve unfamiliar problems, acquire new skill sets, and deal with complex patterns of information.

Fluid Intelligence (Gf): our capacity to reason and solve unfamiliar problems, acquire new skill sets, and deal with complex patterns of information.

IQ & Success

Conventional success can be looked at through three lenses: education, occupation/career, and income. Someone who has been to Harvard or Princeton, has a higher degree with good grades, is an attorney, professor or corporate CEO, and is a high earner, fits most people's stereotype for 'being successful'. What is the evidence for impact of IQ on success?

Education

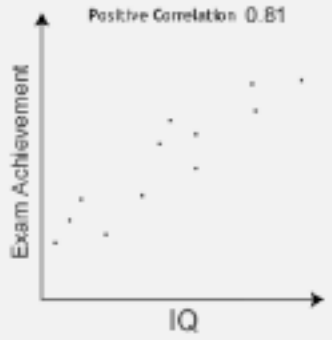
Many hold to the view that the abilities required for success in the real world differ substantially from what is needed to achieve success in the classroom. But the evidence suggests otherwise. Academic performance is a strong predictor for career success and socioeconomic prosperity. (1)

And decades of research clearly show that IQ is the most powerful single predictor of academic achievement - more so than motivation, self-perceptions of ability and personal interests. (2) In one study with a huge sample size (3), Ian Deary and colleagues did a 5-year study, tracking 70,000 + English school children from age 11 years to their national examinations in 25 academic subjects at age 16.

They found that the correlation between *g* (IQ) and educational achievement (GCSE exam scores) was 0.81. Correlations are measured from -1 to 1.

A correlation of 1 would mean that for every incremental increase in IQ, a fixed increase in grades is guaranteed. A correlation of 0.81 means that IQ level doesn't entirely explain the differences in exam scores - there's room for the independent impact of motivation, effort, conscientiousness, and so on - but IQ clearly explains a lot of those differences.

This is what a correlation of 0.81 looks like in a graph, where each point represents a different student's IQ level at 11 years, and their academic achievement level at 16.



Deary found that general intelligence had an impact on performance in all 25 subjects. IQ explained nearly 60% of the differences in math exams, 50% of the differences in English exams, and nearly 20% of the differences in Art and Design assessments.

Of course this means that a big chunk of the differences in academic achievement here are due to other variables than IQ - such as effort, personal interest and learning environment - (particularly in art and design) but IQ is the factor with the biggest impact nonetheless.

We all know that Ivy League students tend to be more successful. In 2014 study, 1139 colleges in the US were ranked according to the students' IQ - assessed via the Verbal and Math SAT scores. The top 10 SAT score colleges are shown here, clearly showing a 'cognitive elites' profile. (4)

School	Average SAT (M + V)
California Institute of Technology	1545
University of Chicago	1515
Princeton University	1505
Harvard University	1505
Yale University	1505
Massachusetts Institute of Technology	1500
Columbia University	1485
Harvey Mudd College	1480
Stanford University	1475
Northwestern University	1470

Stenze's meta-analysis published in 2007, looking at all 59 of the independent studies on the impact of IQ on educational attainment available at the time, found an overall correlation between IQ and educational level of **0.56** - higher than parents' education, SES index and even academic performance (grade average) itself. (5)

Career/Occupation

Employees in almost every job category can expect to face novel problems in a workplace that is changing repeatedly. Familiar responses no longer work, and even newly acquired ones will not work for long.

The American Management Association recently summarized what's needed in the economy.

"Employees need to think critically, solve problems, innovate, collaborate, and communicate more effectively."

According to the Association of American Colleges & Universities (2010) the skills employers want are (6):

1. Applying knowledge in real world settings.
2. Analysing and solving problems.
3. Connecting choices to actions.
4. Being able to innovate and be creative.

These skills are all heavily **fluid intelligence** demanding, and are a symptom of the general conditions of increasing change and complexity.

Jencks and colleagues showed as early as 1979 that even with educational background and socio-economic status (SES) taken into account, IQ measured at adolescence predicted occupational success. (7)

> The key for us, number one, has always been hiring very smart people.
>
> — Bill Gates

Stenze looked at the link between IQ and occupational level in 45 independent studies, with

data from over 72,000 individuals. (5) Occupational level was measured by well-known scales such as Duncan Socioeconomic Index and the International Socioeconomic Index of Occupational Status. There was an overall correlation of 0.43 between IQ and occupation. This compares with a correlation of 0.37 with academic grades, and parents' education, income, occupation and socio-economic status.

Predictors of socioeconomic success

	Number of studies	individuals	Correlation
Correlation with occupation			
Intelligence (all studies)	45	72,290	.43
Father's education	52	132,591	.31
Mother's education	40	116,998	.27
Father's occupation	57	146,343	.35
Parental income	12	60,735	.27
SES index	16	74,925	.38
Academic performance	17	54,049	.37

Intelligence, when it is measured before most individuals have finished their schooling, is a good predictor of career success 12 or more years later when most individuals have already entered stable career. (5)

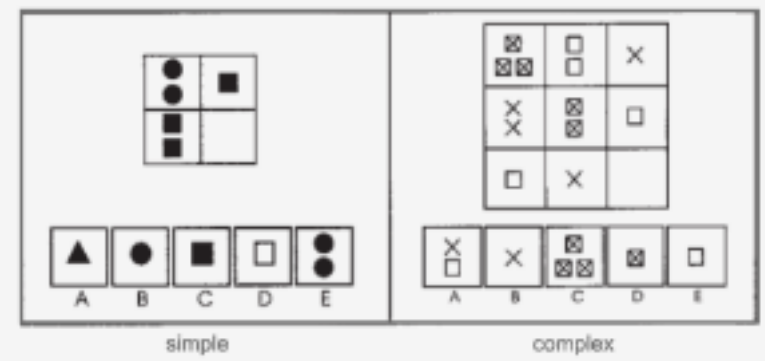
Professor Linda S. Gottfredson, co-director of the Delaware-Johns Hopkins Project for the Study of Intelligence and Society, published a highly influential review '*Where and Why g Matters: Not a Mystery*' back in 2002 that explores in depth why IQ is associated with occupational performance & success. (8) Her analysis is still very much on point for today's work environment.

She shows through a careful look at the data that the further up the occupational hierarchy you go, the more **complexity** you find, and as a consequence the better g predicts job performance. More complexity means, a greater number, variety, variability, ambiguity, and interrelatedness of

information that must be processed to evaluate alternatives and make a decision.

The largest, most consistent distinction among jobs is the complexity of their information processing demands. How critical a position is in an organization, and the general responsibility it involves, both correlate highly with job complexity. More complex jobs tend not only to require higher levels of education, but also lengthier training and experience. The importance of 'updating job knowledge' correlates very highly (0.85) with job complexity.

Comparisons of IQ tests reveal that the more *g*-loaded ones (e.g. fluid intelligence (Gf) matrices tests) are more complex. Gottfredson defines intelligence (*g*) as the general capability for processing complex information of any type.



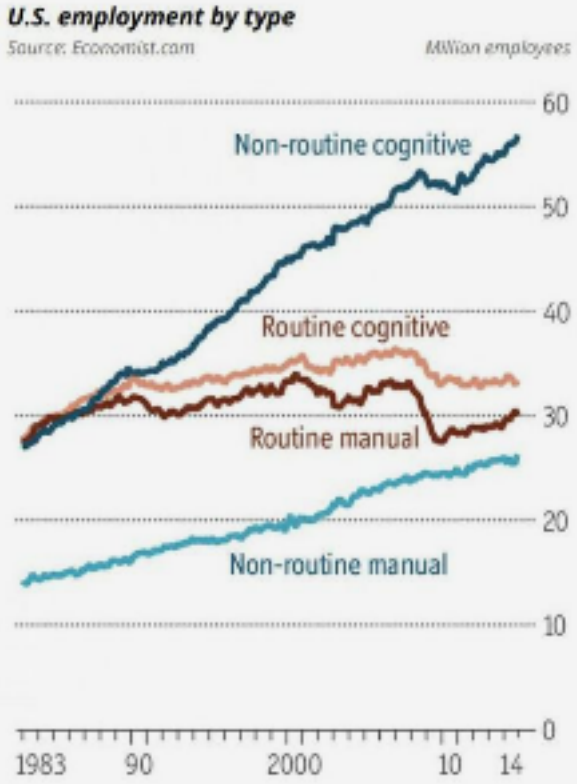
We saw in Unit 2 that more complexity in fluid intelligence tests depends more on slow - rather than fast - problem solving fluid intelligence.

Many job duties can be described as general kinds of problem solving— advising, planning, negotiating, instructing, and managing employees. They are also highly correlated with job complexity. The information processing requirements that distinguish complex jobs from simple ones are essentially the same as the task requirements that

distinguish highly g-loaded IQ tests (matrices tests) from less g-loaded ones (speed of processing tests).

IQ's direct effects on job performance increase when jobs are less routine, training is less complete, and workers have more autonomy. High *g* people tend to possess a lot of knowledge in their jobs, but its accumulation is a by-product of their ability to understand better and learn faster. This knowledge is their crystallized intelligence (Gc).

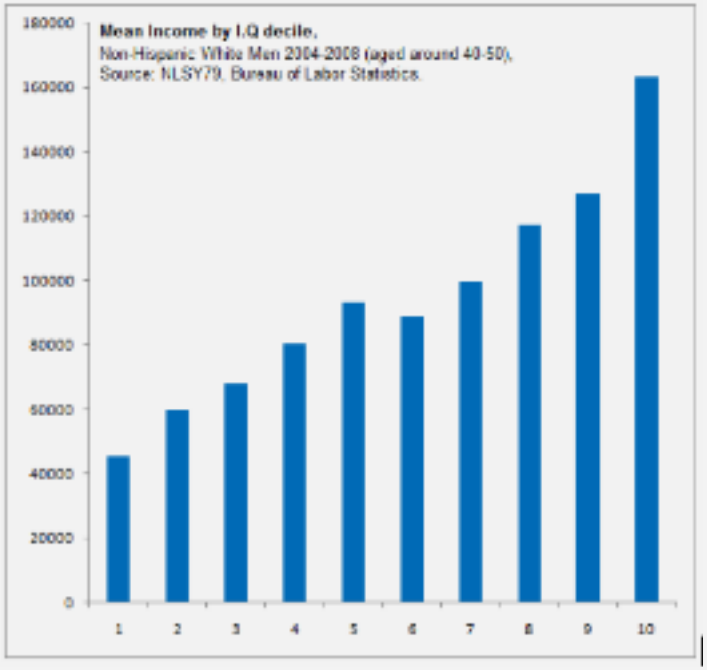
The graph here shows data about the changing nature of work published in The Economist. Work is becoming more complex, and less routine. We can infer from this that fluid intelligence has high **adaptive value** in today's fast-changing economy.



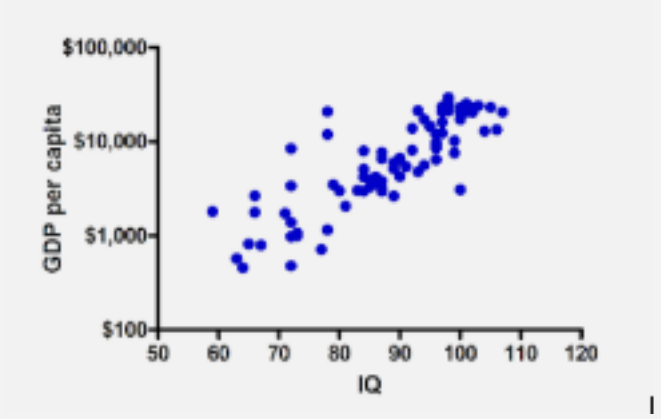
Income

The high correlations between IQ and job status and performance does not map cleanly to financial success. How much money a person makes is difficult to explain by any single variable. In Stenze's meta-analysis of 31 studies looking at the IQ-income link, the overall correlation was only .20 - actually the same as the association between parental income and salary. (5) The best predictor of a person's income was found to be their educational level with a correlation of .29.

Despite the lower correlations, IQ's impact can be felt. Here is data from the US Bureau of Labor Statistics showing mean income as a function of IQ decile.



Research 2007 showed that each point increase in IQ test scores predicts an income income increase between $234 and $616 per year after holding a variety of factors such as education and socioeconomic class constant. (9) More dramatically, Here is data showing GDP per capita for different nations as a function of average national IQ:

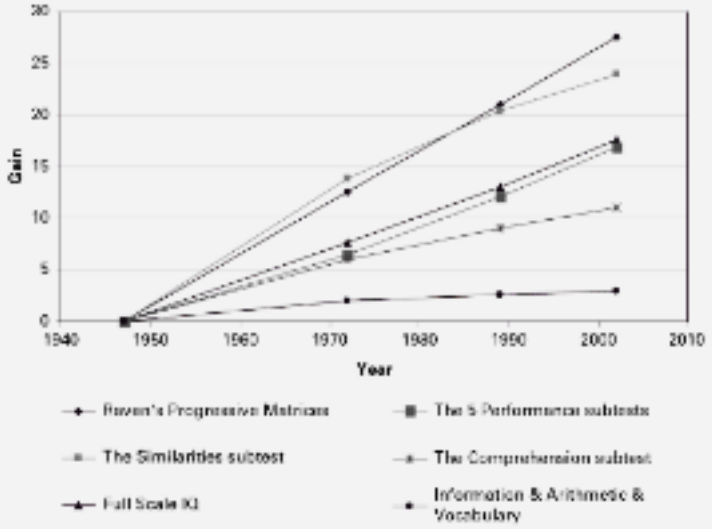


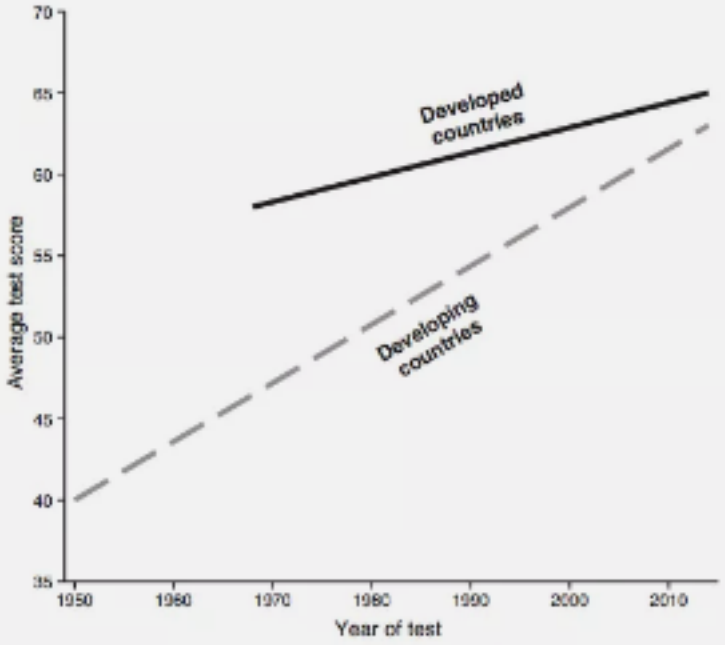
In a 2011 study, Rindermann & Thompson looked at the IQ-wealth link of 90 countries, and found that for each one-point increase in a country's average IQ, the per capita gross domestic product (GDP) was $229 higher. For the smartest 5% of the population in each country it made an even more dramatic difference to salary: for every additional IQ point in that group, a country's per capita GDP was $468 higher. (11)

Based on data like this, Rindermann has devoted a lot of his work to the 'smart fraction' theory of development. This claims that intelligence improves productivity, production, income and prosperity at the individual, institutional and societal levels. And this process depends especially on the proportion of the population that is above a particular 'high IQ' threshold - such as an IQ of 120 or higher. (12)

> "IQ is relevant for technological progress, for innovation, for leading a nation, for leading organizations, as entrepreneurs, and so on."
>
> — Heiner Rindermann

In more recent research (13) confirms Rindermann's smart fraction theory, and finds in addition that **rising intelligence levels** has been a major determinant of economic growth in the recent past. Over the past few decades there have been large increases in fluid intelligence test scores globally - particularly in fluid intelligence. This phenomenon is known as the Flynn effect, and we shall be revisiting it in Unit 5. The first graph is US data.





▲ Figure 5.1 The Flynn Effect. Results of a worldwide review of 734 studies that used the Raven's Progressive Matrices test (similar to the 'matrix reasoning' puzzles in Figure 2.1). Intelligence test scores have improved more in the developing world (dashed line) than in the developed world (solid line). Note that the test studied here isn't a full IQ test, so the average score isn't 100. (Figure adapted from Wongupparaj et al., 2015.)

Worldwide increases in IQ over the past few generations have had a major impact on the wealth of nations.

IQ, The Attention Economy & Autonomy

We noted there is now a strong pressure for managing a proliferation of **choices**: economic, socio-cultural and political. In our work environments our information processing abilities may be **stressed** by deadlines, frustration and interpersonal conflict, or overwork (8) , putting us at risk of burnout. And more generally, we live in a world where distractions and diverse interests continually compete for our **attention**. Attention is used to filter information from the large pool of information surrounding us in the digital age - and this filtering can be controlled both proactively and reactively. In our 'always on, always connected' world, attention is a limiting factor in the consumption of information.

The prescient cognitive scientist Herbert A. Simon was perhaps the first to articulate the concept of the 'economics' of attention back in 1971:

"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."

Attention is a scarce resource, and producers of information (mainstream and social media, marketing and PR agencies, governments, etc) are

strongly motivated to control or access it and there is increasing pressure on us to manage its allocation.

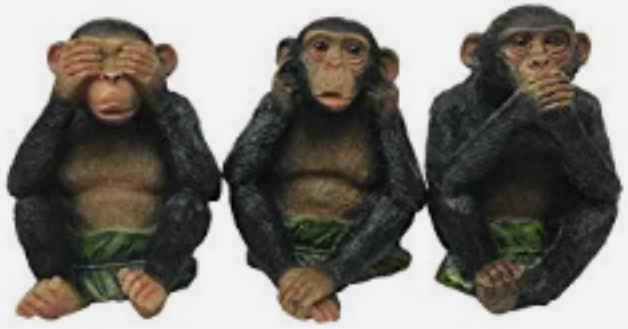
Whether in terms of choices, stress on information processing demands, or competition within the attention economy, adapting to the contemporary situation requires much more autonomy and self-regulation than in the past.

How Does IQ Help With Our Autonomy?

General intelligence (*g*) helps our autonomy and choices through the overlap it has with attention control, and self-regulation. With a higher IQ we are more capable of controlling our attention, and less likely to get side-tracked, lose sight of our long-term goals, or succumb to self-defeating addictions.

There is a strong relation between executive attentional abilities and both fluid intelligence and working memory capacity: the ability to control attention consistently dissociates people who score high and low on measures of working memory capacity. (14) Working memory mediates the link between intelligence and attention. (15)

and general intelligence in not only humans but also chimpanzees! —a relation that reflects the role of inhibitory control during cognitive processing of information and intelligent decision-making. (16, 17)



High IQ individuals are more forward-looking: they are more likely to save for retirement conditional on saving. They are better at factoring their future selves into their decision-making in the present, and are

less susceptible to what is called 'delay discounting' - which is preferring smaller, sooner rewards to larger, later ones. (18)

IQ Augments Skill Learning

Developing sensorimotor skills involving coordination and timing – whether for game playing, playing musical instruments, to competing in mixed martial arts – also benefits from a higher IQ.

Psychomotor ability (Gsm) is a recognized 'broad ability' of intelligence. While learning new, complex skills there is an initial cognitive stage where skill-related mental models, rules and strategies are learned, and then a perceptual & motor stage, where perception and action become increasingly coordinated and automatic and optimal timing and fine-tuning develops with practice. Fluid intelligence has been found to be especially critical in the first stage and higher IQ individuals learn skills better as a result. (19)

Sensorimotor skill in BJJ

IQ Augments Creativity & Innovation

Harvard psychologist Howard Gardner defined general intelligence as:

"the ability to solve problems, or to create products, that are valued within one or more cultural settings."

Creating products can be seen as in many ways analogous to working on a problem. As we saw in Unit 3, general intelligence (*g*) can be differentiated into fluid intelligence (Gf), our 'CPU', and crystallized intelligence (Gc), our stored knowledge base. Remember...

$$g = (Gf \cup Gc)$$

$$IQ = g$$

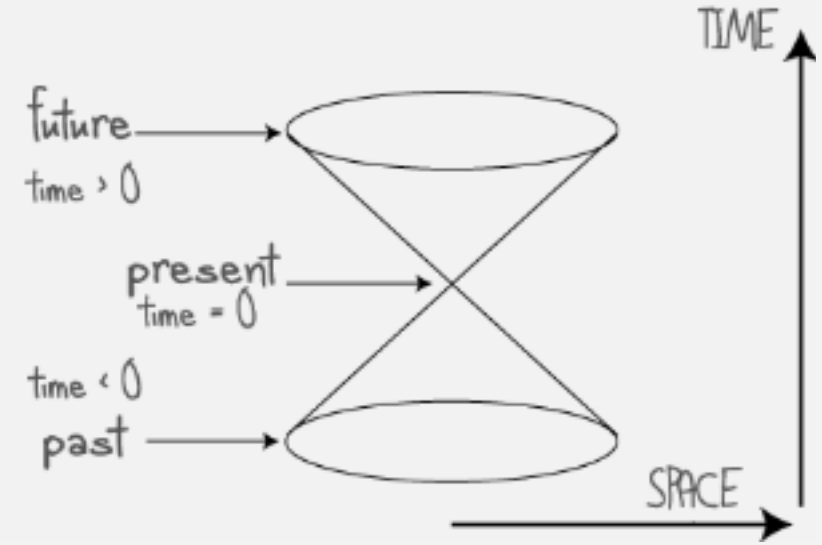
The table here is from a meta-analysis of multiple independent studies on the role of IQ in creativity. It summarizes the links that have been found between *g* and three different expressions of creativity. (20) Pluses mean significant IQ impact; the more crosses, the more the contribution. IQ has impact across the board. Entrepreneurial creativity isn't in this table but I'd expect ++ contributions since it's more constrained than artistic or everyday creativity, but not as much as scientific creativity.

Trait	Artistic creativity	Scientific creativity	Everyday creativity
Intelligence			
Fluid	+	+++	+
Crystallized	++	+++	+

Your IQ LightCone & Self-Actualization

- - - - x

In the geometry of spacetime in physics, for any event, we can describe everything that can possibly be causally connected to the event by a light cone (since nothing can travel faster than light) that expands into the future and the past from the present (time = 0), shown below. Anything outside of this cone can have no interaction with or connection to that event (since nothing travels faster than light).



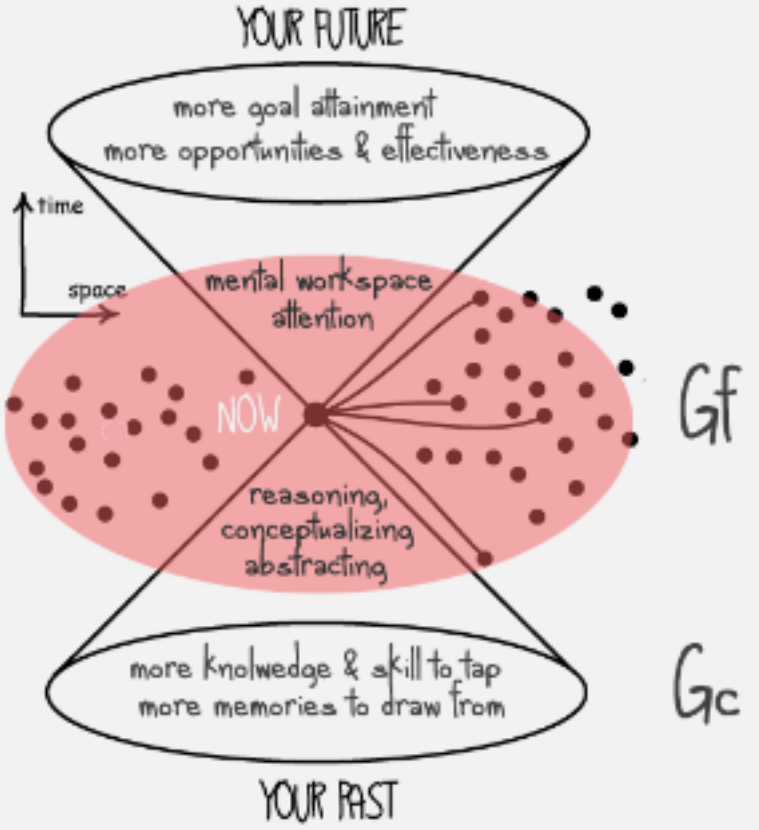
The future of any event (what might happen to it, how it might change) consists of events inside the future half of the light cone. Likewise, the past of any event (what has happened to it) is picked out by events in the bottom half of the light cone.

That's events in spacetime geometry.

We can use the spacetime lightcone as a conceptual model for intelligence if we define intelligence in an action-and success oriented way, as Sternberg does:

". . . 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."

Understood in this way, this is what your IQ lightcone looks like:



You have to imagine your life here in terms of your past - what you've experienced and learned and can bring to bear on the present - and your future - what your are capable of foreseeing and doing.

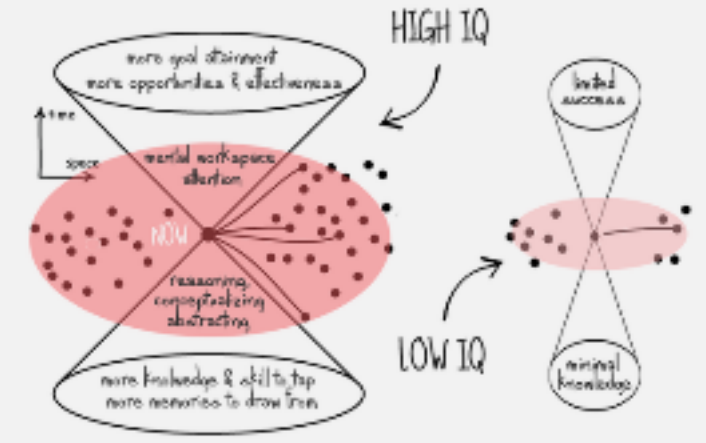
When you use your fluid intelligence effectively, you proactively, reason, make connections and abstract better in the 'workspace' of your working memory. As a result, you can both:

> ...**learn** better, with more functional neuroplasticity change, as you expand your skills and knowledge and experience in the cone of your past. This is your crystallized intelligence (Gc).
>
> ... **understand** more of how the situation can evolve and the scope of options available to you, and as a result you follow better solution paths leading to greater goal-attainment, effectiveness and success.

Remember your fluid intelligence is the interaction of your working memory (WM) and your learning and retrieval ability (Glr).

$$Gf = (WM \cap Glr)$$

Your fluid intelligence is thus a bottleneck in the lightcone of your life. The more Gf ability you have over time, the larger your lightcone - and the more overall 'volume' you have in the 'capacity' of your past and future.



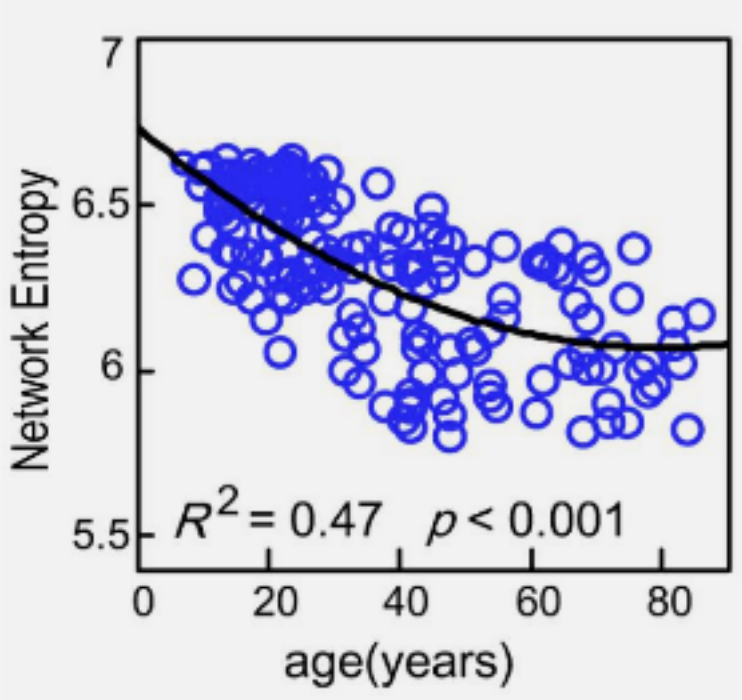
Brain Entropy & IQ

Is there any evidence for this conception of intelligence, aside from its appeal as a thought experiment?

Actually there is - in the research looking at the link between brain **entropy** and IQ.

Entropy is a measure of the complexity and irregular variability in brain activity from one moment to the next. It measures the number of neural states a given brain can access and is marked by greater long-distance correlations in brain network activity. Low entropy is characterized by orderliness and repetition, and less long-range network synchrony.

You see the lowest levels of entropy when we are in deep sleep - and, at the extreme, coma. Brain entropy is lower in individuals with ADHD. And brain entropy decreases with age as shown in the graph. (21)



According to cognitive neuroscientists studying this phenomenon, with more entropy (and thus complexity) in the brain's connectivity, it can better

adapt to dynamically changing environments rich with unpredictable events. Glenn Saxe and his colleagues at the New York University School of Medicine claim brain entropy can be understood as:

“a measure of the brain’s overall flexibility or readiness to encounter unpredictable stimuli …to model and predict the outcomes of a complex, chaotic world”

Saxe and his team measured brain entropy using functional MRI scanners in 900 healthy participants, who also completed measures of their verbal intelligence and reasoning ability outside of the scanner.

They found that brain entropy correlates with intelligence. Vocabulary performance and superior reasoning ability was associated with greater entropy in the frontal regions of the brain. The entropy-IQ link was apparent in bilateral prefrontal areas, which are important for **fluid intelligence** involved in information processing & inference more so than for crystallized intelligence involved in accessing stored knowledge such as vocabulary. (22) Saxe’s team concludes that entropy is a reliable predictor of IQ.

Some scholars understand the intelligence-entropy link explicitly in terms of IQ lightcones.

In very broad terms, entropy can be understood as a measure of the number of possible states a system can branch into over time. According to Alexander Wissner-Gross (23), a physicist at Harvard University and the Massachusetts Institute of Technology, intelligent behavior in any system - not just human brains - is the

"physical process of trying to capture as many future histories as possible"

Future histories are the set of possible future outcomes/options available to a system at any given moment. The higher the amount of entropy a system has, the more future histories are available.

Intelligent behavior maximizes the system's entropy over the long-term according to Wissner-Gross's theory .

> Intelligence should be viewed as a physical process that tries to maximize future freedom of action and avoid constraints in its own future.
>
> — Dr. Alexander D. Wissner-Gross

On this entropy-based theory of intelligence, committing to goals is "investment in future bottlenecks in path space". Goals are seen as short-term bottlenecks that open up more expansive future possibilities over the longer-term.

Intelligent action that opens up future possibilities can be seen as inherently creative as well as adaptive, expanding the lightcone of our future.

Wellbeing & IQ

Both self-efficacy ("how well one can execute courses of action required to deal with prospective situations") and our perceptions of possibilities are important correlates of **psychological well-being**.

People who report seeing more possibilities in their futures are happier and more satisfied with life, feel more purpose in life and experience more self-efficacy. (24)

Summary

In this Unit you have seen the data on the critical role of IQ in many valuable outcomes in life - from education, occupational status & income, to skill acquisition, to self-regulation and the capacity to actualize future possibilities.

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Evidence-Based Brain Training

Unit 6

In this Unit, I'll be presenting the evidence for the effectiveness of both app based brain training or computerized cognitive training (CCT) as well as other bioenergetic strategies such as exercise and intermittent fasting.

Brain Training Research: The Current State of Play

The computer app brain training industry has been fraught with controversy. In January 2016 Lumos Labs, the company behind the popular brain-training program Lumosity, had to pay out a $2 million settlement to the Federal Trade Commission (FTC) for running deceptive advertisements.

Fast forward a few years. If you now look on the Lumosity website now in 2019/2020 you can see the following: *"There have been over 20 peer-reviewed publications in academic journals using Lumosity games or assessments. ...After ten weeks, the Lumosity group improved in performance across a battery of cognitive assessments [and] showed statistically significant improvements on subtests of working memory, arithmetic reasoning, and processing speed."* (1)

It's clear that progress has been made in the industry. As an experiment, I Googled 'does brain training work' (left screenshot); also 'cognitive training' in Science Direct - the science portal (screenshot right) and got the following results.


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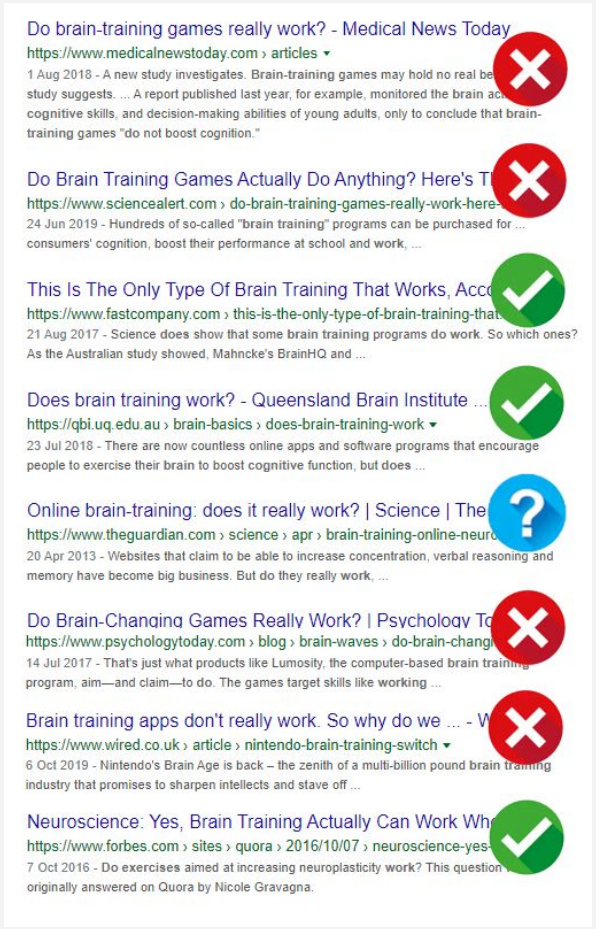
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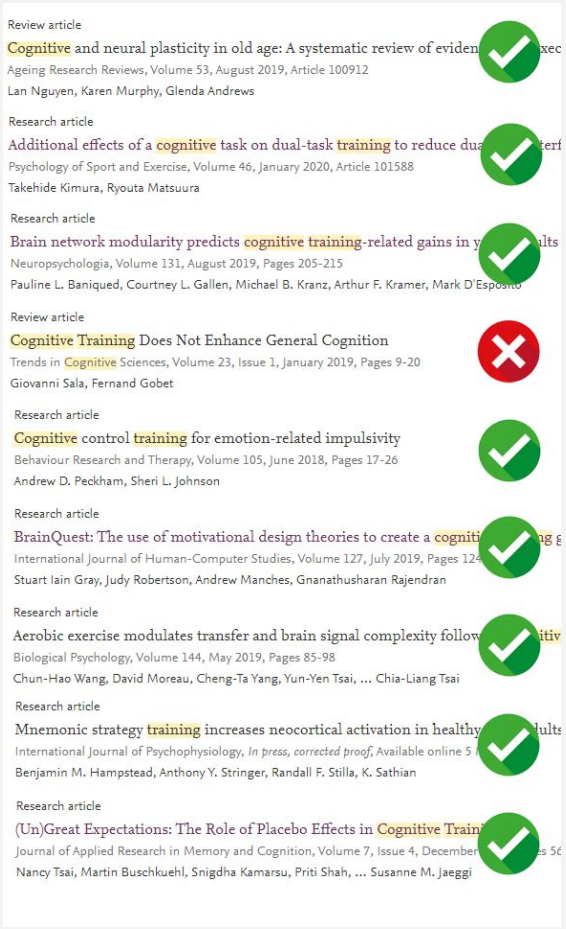
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Nancy Tsai, Martin Buschkuehl, Snigdha Kamarsu, Priti Shah, ... Susanne M. Jaeggi

Green ticks, green crosses and blue question marks indicate whether the article evaluated brain training as being effective or not.

The Google search articles (left panel) were all popular science articles in online media such as Wired or The Guardian. In this domain, there were 3 for brain training, 4 against, and 1 undecided.

The Science Direct articles (right panel) we see the latest (2018-2020) brain training studies (called 'cognitive training' in cognitive neuroscience), reported in peer reviewed scientific journals. The greater majority are reporting positive effects of brain training. The selection shown does not include all the studies that report positive effects for mild dementia, addictions, mental health disorders, and so on.

You can easily recreate this experiment yourself. Keyword 'cognitive training' in Science Direct.

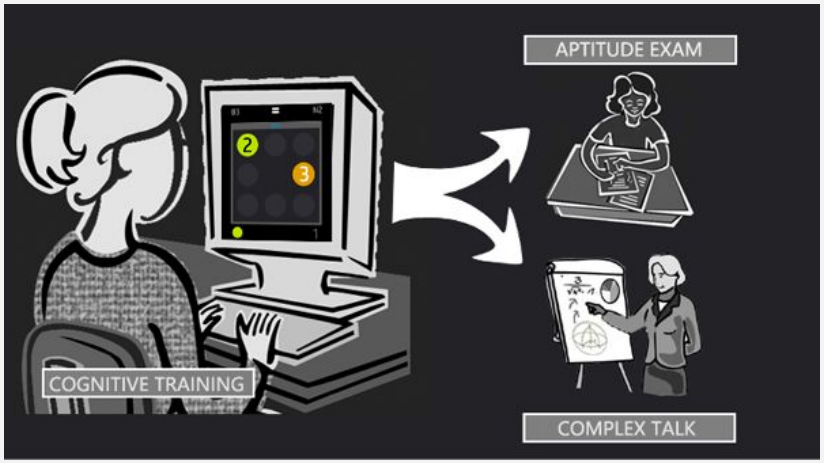
This gives you a clear window into the actual brain training research in cognitive neuroscience labs that is being produced, month on month - not the Google-ready popular science take on it. This is behind the curve. Actual research has a positive trajectory, and is taking brain training in new, promising directions.

My goal in this Unit is to summarize for you the overall state-of-play for evidence-based computerized brain training and it's cutting edge trajectory.

The goal of evidence-based brain training: Far transfer

Well designed brain training results in far transfer effects – the skills you get from practice with the

brain training games transfer beyond the game to general-purpose cognitive abilities like IQ, memory, mental flexibility, and attention control. This is contrasted with simply practice effects which you see with most video games – where training benefits are very specific and limited to your skill with that game, or near transfer gains where the training only helps with closely related cognitive tasks.



Dual N-Back Training

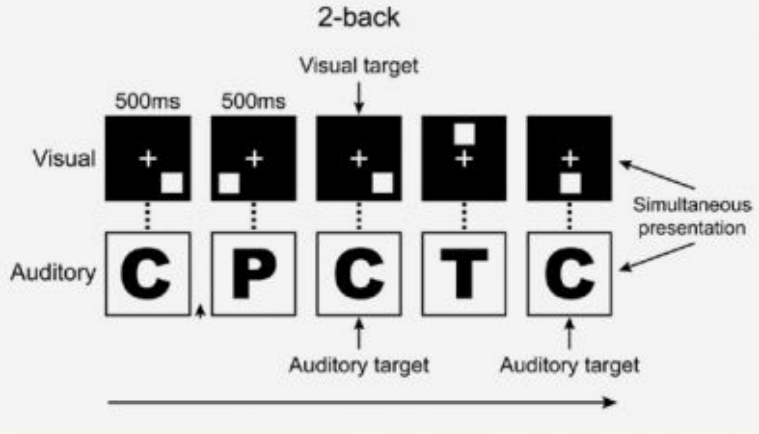
As you have learned in previous Units, there is a close link between working memory and fluid intelligence (IQ).

In combination with attention control, your working memory functions like a mental workspace. Its job is to store task-relevant information for ongoing goal-directed information processing while inhibiting distractors or automatic responses.

People differ in the capacity or 'bandwidth' of their working memory, and differences in working memory capacity (WMC) strongly predict IQ levels.

One of the most well-known working memory training methods is the **dual n-back** (DNB).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.



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

How to play this game is explained in my tutorial [DNB video here](). (2)

To evaluate the **far-transfer effectiveness** of DNB training, we use don't look at individual working memory brain training trials, but meta-analysis of all the dual n-back studies that have been published.

A meta-analysis uses a statistical approach to **combine** the results from multiple studies to reduce the possibility of missing effects when they exist, improve estimates of the **size** of the effect in standardized units and/or to resolve uncertainty when reports disagree.

To give you an idea of what this means in practice, here is an earlier meta-analysis published in 2013 (3). It shows the working memory (DNB) brain training effects on spatial working memory capacity for numerous different studies (each dot is the average, the lines are the range), and the overall average of all studies (the heavier dot at the bottom).

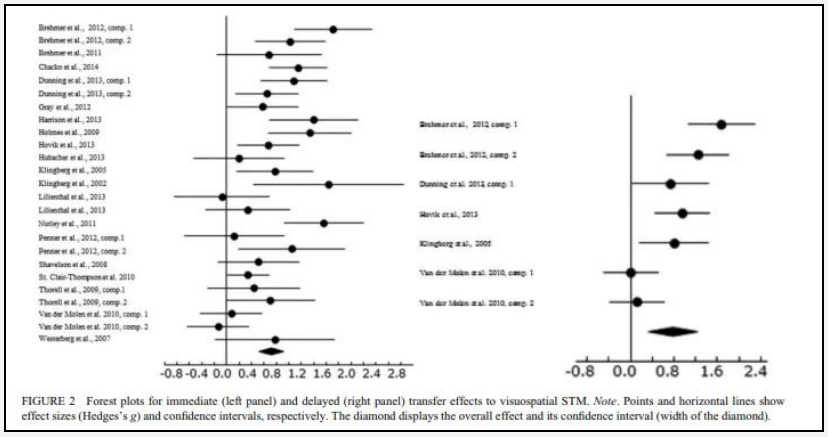


FIGURE 2 Forest plots for immediate (left panel) and delayed (right panel) transfer effects to visuospatial STM. *Note*. Points and horizontal lines show effect sizes (Hedges's *g*) and confidence intervals, respectively. The diamond displays the overall effect and its confidence interval (width of the diamond).

Short-term gains are shown on the left and long term (tested up to 1 year after training) gains on the right. The units are standardized, with 0 being no effect from training. As you can see, the average spatial working memory gain (both short term and maintained long-term) is 0.8 which is **~9.5 standardized points**.

Keep in mind that working memory (Gwm) is one of the broad factors of full-scale IQ: it is a component of *g* of that is measured by classic tests such as the WAIS-IV - as we saw in Unit 1.

And here is another meta-analysis from 2015 (4) showing training gains in standardized points for a number of different IQ related abilities.

TABLE 3
Transfer Effects Following WM Training

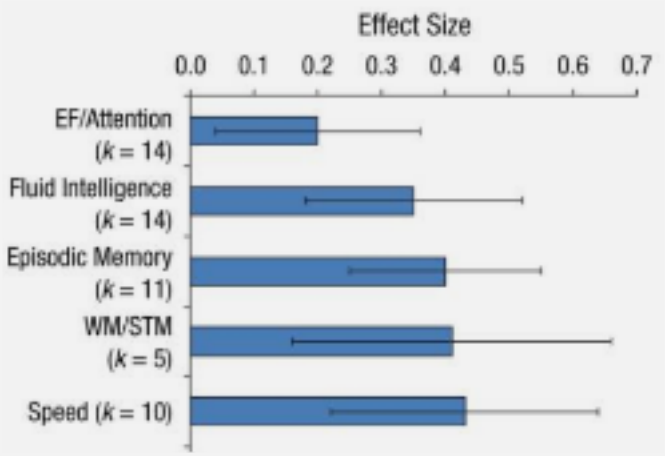
Transfer Effect	*No. of Effect Sizes (k)*	*Effect Size g*
Verbal STM (short-term/long-term)	32/9	5.5 / 3.3
Visuospatial STM (short-term/long-term)	25/7	10.8 / 11.7
Verbal WM (short-term/long-term)	42/11	8.2 / 5.2
Visuospatial WM (short-term/long-term)	19/6	9.5 / 6.3
Nonverbal ability (short-term/long-term)	45/11	0.2 / 0.0
Verbal ability (short-term/long-term)	29/5	2.4 / 3.9

Note. STM = short-term memory; WM = working memory;

Schwaighofer et al., 2015

The standardized point gains are shown both when tested short-term and long term (6-12 months after training). K is the number of independent studies - in different labs - that are used to estimate the true, unbiased effect size.

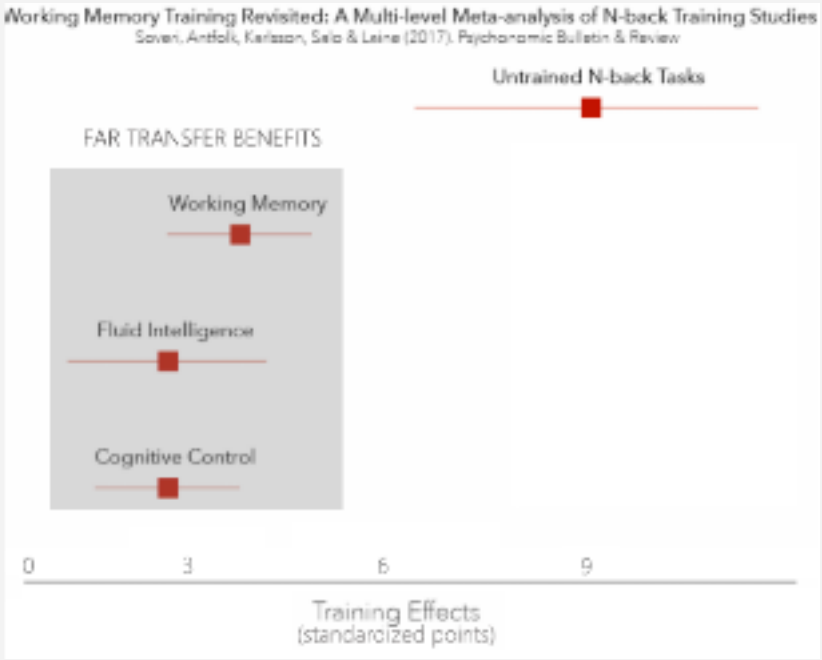
And here is the data from another meta-analysis entitled *Making working memory work: A meta-analysis of executive control and working memory training in younger and older adults.* (5)



An effect size of 0.4 is equivalent to 6 standardized IQ points.

The latest 2017 meta-review that uses the most conservative analysis criteria for 33 published, randomized, controlled dual-n-back trials from independent labs all around the world (6) 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)
- Cognitive/attention control



This data is consistent with a study in 2015 looking at just fluid intelligence (Gf) gains from dual n-back training (7). The authors of this meta-analysis conclude:

> We urge that future studies move beyond attempts to answer the simple question of whether or not there is transfer [from training to increases in IQ] and, instead, seek to explore the nature and extent of how these improved test scores may reflect true improvements in intelligence that can translate into practical, real-world settings.
>
> -Jacky Au and colleagues, University of California, April 2015

Will this kind of DNB effect size make a difference in your life?

How should we interpret these effect sizes from DNB brain training? Will they make a difference in your life?

The effect size for working memory capacity (Gwm) is around 0.25. Let's take another kind of intervention to compare. This is the same effect size of antidepressants such as Fluoxetine in treating depression. (9) 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.

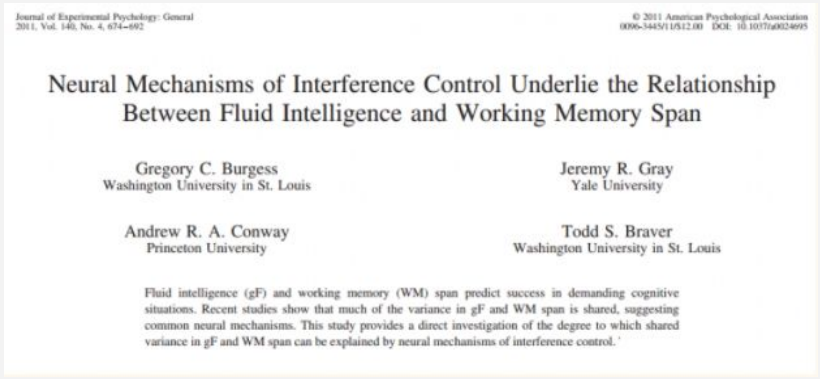
Combined with IQ multiplier effects (Unit 5) these IQ gains can make a difference in your life for sure.

DNB + Interference Training

Interference control is the ability to filter out distracting information from previous contents of working memory.

Brain imaging work by Professor Tod Braver (a fellow grad student) and colleagues has shown that interference control ability underpins the association between fluid intelligence (Gf) and working memory (Gwm). (10)

Working memory capacity only strongly predicts IQ if there is also interference control: take interference control away and the relationship between WM and IQ reduces considerably. (11)



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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Andrew R. A. Conway
Princeton University

Todd S. Braver
Washington University in St. Louis

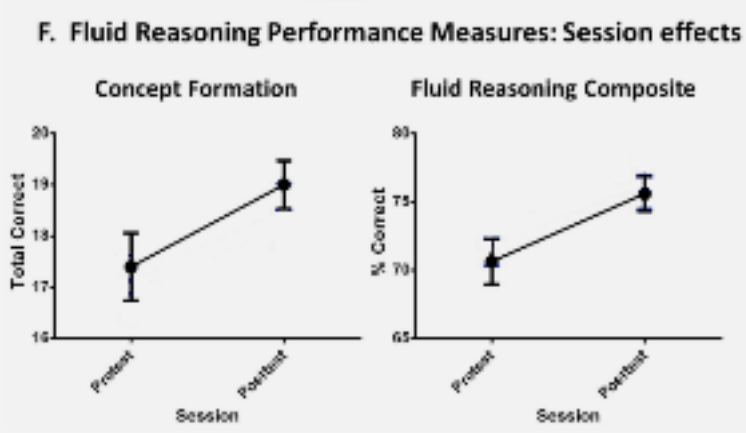
Fluid intelligence (gF) and working memory (WM) span predict success in demanding cognitive situations. Recent studies show that much of the variance in gF and WM span is shared, suggesting common neural mechanisms. This study provides a direct investigation of the degree to which shared variance in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

Lab studies looking at DNB + interference control (IC) training show **stronger far transfer effects** than dual n-back training alone.

One DNB + IC study found relatively more gains in attention control, and increased electrical signalling in the parietal cortex, part of the frontoparietal hub network of IQ. They argued this *"may be related to improvements in processing speed, attentional control, or both"*. (12)

In a 2017 study Erika Hussey and colleagues, found DNB + IC training (compared to standard DNB) resulted in greater improvements in both memory and language. (13)

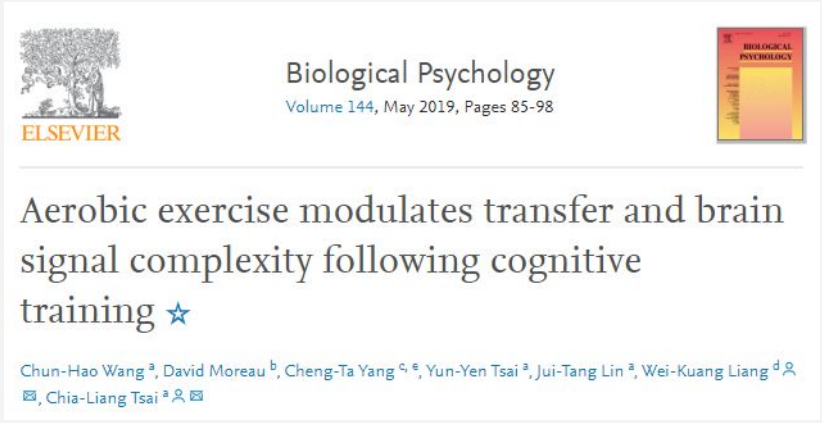
A recent 2019 DNB + IC study, published in the prestigious journal *Cognition,* found far transfer gains in IQ (Gf) of 6 points. (14)



All IQ Mindware apps combine interference control training with dual n-back training.

Multimodal Training

Multimodal training combines other strategies with app based brain training.



Biological Psychology
Volume 144, May 2019, Pages 85-98

ELSEVIER

Aerobic exercise modulates transfer and brain signal complexity following cognitive training ☆

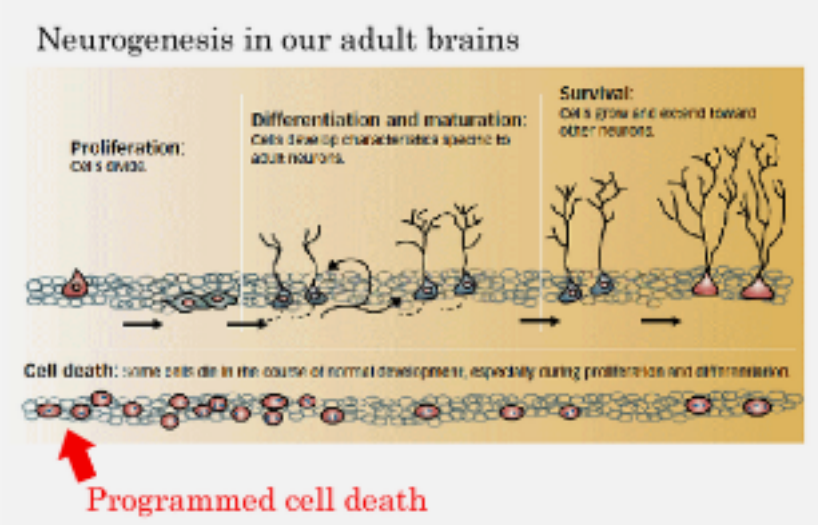
Chun-Hao Wang [a], David Moreau [b], Cheng-Ta Yang [c, e], Yun-Yen Tsai [a], Jui-Tang Lin [a], Wei-Kuang Liang [d] ✉, Chia-Liang Tsai [a] ✉

Several research groups have become interested in the extent to which cognitive training can be enhanced synergistically by bioenergetic interventions such as exercise or intermittent fasting.

Exercise Combined With Working Memory Training

Let's look at what we know already for the brain effects of exercise.

Work by Dr Tracey Shors at Rutgers (15) and others has shown that exercise can greatly increase the number of new neurons produced in adult brains each day – a process called neurogenesis. Neurogenesis can produce many thousands of new brain cells per cubic millimeter per day – throughout the lifespan.



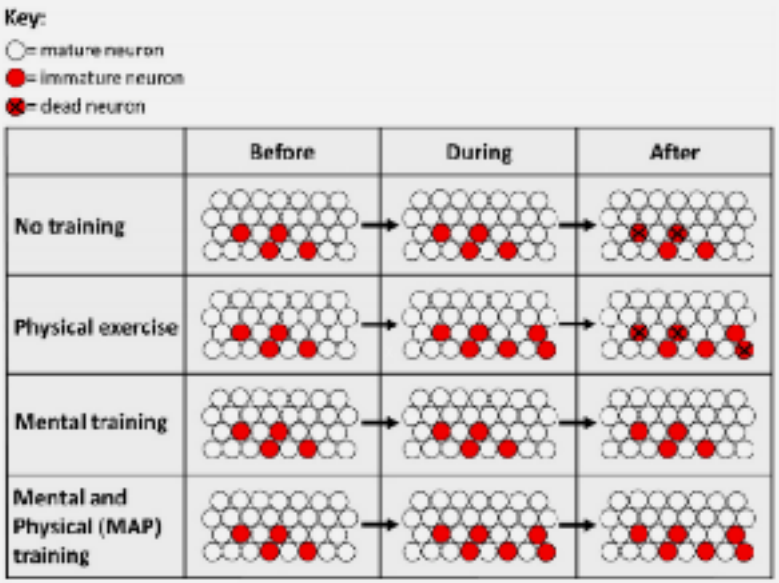
A high proportion of these brain cells will typically die within several weeks of being born, particularly if we are chronically stressed! They don't differentiate into mature neurons that get wired into brain circuitry. They go through a process of programmed cell death.

What Shors has found is that mental activity combined with physical activity stops the programmed cell death allowing the new brain cells to become integrated into new, functional circuits that help cognition.

"Physical activity, especially aerobic exercise greatly increases the number of new neurons that are produced in the brain. In contrast, mental training via skill learning increases the numbers that survive, particularly when the training goals are challenging. Both manipulations can increase cognitive performance in the future." Curlik & Shors, 2013

.

Exercise and mental training work in different ways. Exercise grows new brain cells, while mental training stops the new cells from dying and enables them to be used. Shors calls this **MAP training** (which stands for 'Mental and Physical Training'). Here's how she depicts this multimodal training process. The x's show cell death.



Shor has apply MAP training to effectively help treat depression (17) but she hasn't looked at applying it to increasing IQ or cognitive performance.

Multimodal training for IQ

A seminal study entitled *Multimodal Fitness and Cognitive Training To Enhance Fluid Intelligence*, published in 2017 in the journal *Intelligence* (18), has applied multimodal brain training increase IQ.

Ana Daugherty and her colleagues demonstrated significant IQ gains from multimodal training – more than for cognitive training or fitness training alone. The brain training results and their conclusion summary are shown below.

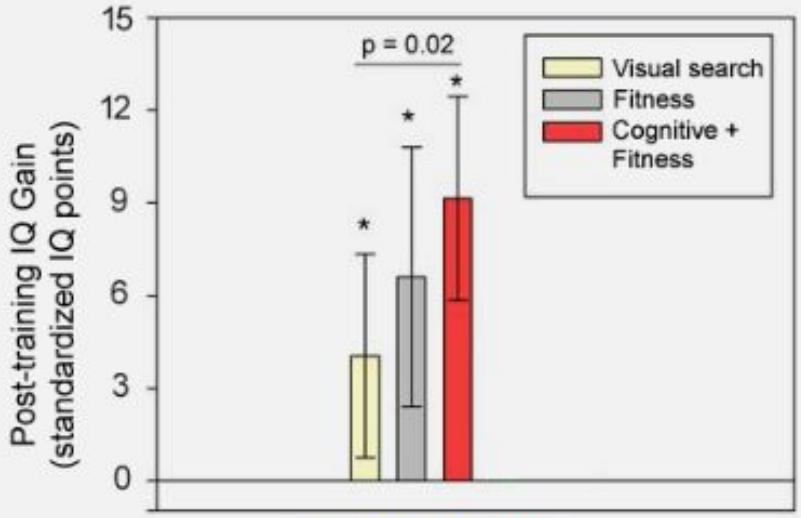


Fig. 4. Group differences

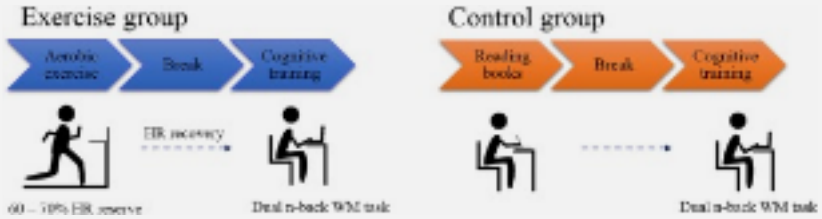
Highlights

- Fitness-cognitive-mindfulness interventions were designed to bolster intelligence.
- Fitness-cognitive training showed control-adjusted gains in visuospatial reasoning.
- Fitness only training did not bolster fluid intelligence performance.
- Individuals varied in benefits to fluid intelligence from mindfulness training.

Here we're looking at a **9 point** IQ (fluid intelligence) gain.

A more recent May 2019 multimodal brain training study (19) asked the following question:

Can aerobic exercise combined with dual n-back training result in greater working memory training benefits than DNB training alone? This diagram from their paper shows the training protocol they used.

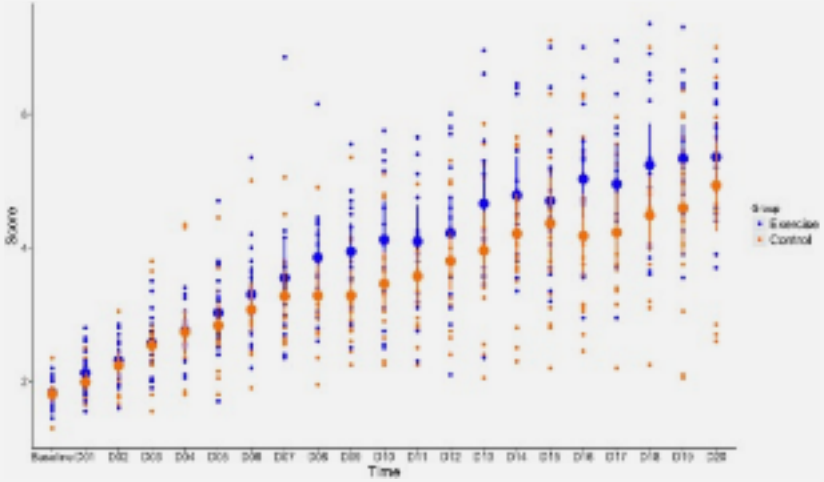


The cognitive training regimen lasted 5 weeks, with a 4-day/week schedule with training sessions similar in length to 2 IQ Mindware app sessions per day. For exercise, they did a 30-min running bout on a treadmill - a 5-min warm up, 20 min of aerobic exercise at moderate intensity (i.e., 60–70% heart rate reserve, and a 5-min cool down.

As they trained their n-back performance increased - with those doing the exercise (in blue) gaining a little more than the non-exercise group (in orange). The

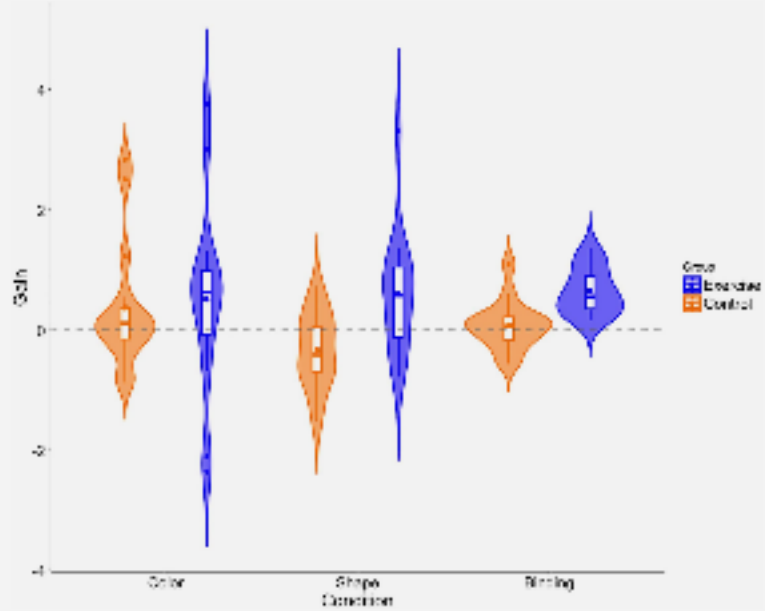
little dots represent the individuals scores, and the large dots the averages for the session.

If you have played the dual n-back you can see how your own performance compares!



After training, working memory – one of the factors of full-scale IQ – was measured by 3 completely different tasks than the dual n-back, so any training gains found were sure to be general purpose – not just related to dual n-back game skills.

They found a very clear advantage in training gains from multimodal training – shown in their data here. The effect size was impressive, and the advantage was the greatest when the working memory task was the most cognitively challenging – at around 10 points.



Conclusion

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A picture that is emerging is that DNB based working memory training works, and that far transfer effect sizes can be augmented by bioenergetics-based multimodal fitness training. We have looked at data on the effects of exercise. There is also promising data showing related benefits from intermittent fasting which targets the same mechanisms resulting in enhanced adult neurogenesis. (20)

This multi-modal training can be further augmented by adding interference control and other cognitive function specific variations to classic DNB training – as implemented in the IQ Mindware apps.

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Cognitive Capacity Gaps & Expected IQ Gains

Unit 7

In this final Unit, I'll be explaining the idea of cognitive **capacity gaps** - where existing capacity does not meet the required cognitive demands for attaining your goal or goals. These gaps can be **intrinsically motivating** for taking measures to augment IQ, particularly when you start to see results with your goals as a result of reducing the gap.

An **extrinsic motivator** for augmenting IQ is to set yourself realistic benchmarks for improvement where you can track your own progress - and in this Unit I'll give you two methods for giving yourself benchmarks.

Intrinsic Motivation: Cognitive Capacity Gaps

To convey more vividly what's meant by cognitive capacity gaps and the measures people have taken to reduce those gaps I'm going to present some unusual examples in the domain of nootropics - smart drugs - following up on the *Limitless* theme introduced in Unit 5.

1. In the movie *Limitless*, Eddie Mora had a book contract. A pressing goal in life was to write his book to turn in to his editor. But when he tried to focus on the task - by sitting in front of his computer monitor, with a coffee and no distractions, by 'staying in the room', he can't overcome his writer's block. He fails to generate any ideas, any words to put to paper. The book-writing task he has set himself is simply beyond him - he doesn't have the capacity for it.

Until....NZT-48 that is! After taking this extraordinary (but highly risky) nootropic, his ideational fluency went through the roof and he was able to complete his book within a matter of days.

2. If you think Eddie Mora's strategy is just fiction, think again! The writer Graham Greene at one point in his writing career needed to make money, so he conceived of a popular thriller - *The Confidential Agent*. To get this book complete as soon as possible, so he could focus on his more serious work, he

took Benzedrine tablets twice daily, one upon waking and the other at midday. As a result he was able to write 2,000 words on his book in the mornings alone, as opposed to his usual 500. After only six weeks, *The Confidential Agent* was completed. Without the drug, Green didn't have the capacity for his level of output.

3. The libertarian intellectual Ayn Rand took up Benzedrine to help her finish her novel, *The Fountainhead*. She had spent years composing the first third of the novel; thanks to the new pills, over the next twelve months she averaged a chapter a week!

4. In the domain of analytical intelligence, the Hungarian Paul Erdös was one of the most brilliant and prolific mathematicians of the 20th century.

He published a record 1,500 mathematical papers during his lifetime and routinely put in 19 hour days. (He died very shortly after solving a geometry problem at a conference in Warsaw.) He owed his mathematical genius and phenomenal productivity to espresso shots, caffeine tablets, and amphetamines the story goes. He took 10 to 20 milligrams of Benzedrine or Ritalin daily.

> Concerned about his drug use, a friend once bet Erdös that he wouldn't be able to go drug-free for a month. Erdös went cold turkey and won the bet but when he came to collect his money, he told his friend, "*You've showed me I'm not an addict. But I didn't get any work done. I'd get up in the morning and stare at a blank piece of paper. I'd have no ideas, just like an ordinary person. You've set mathematics back a month.*"

These are all examples where cognitive capacity has been lacking. The capacity gap has been felt to be so compelling that each of these individuals turned to nootropic drugs to augment their capacity and attain their goals.

But taking addictive nootropics isn't a good general strategy. It comes with costs to overall health and self-regulation.

The great poet Auden, who also used amphetamines for his work, makes the point succinctly: While he saw them as one of the "labor-saving devices" in the "mental kitchen," he was aware that "these mechanisms are very crude, liable to injure the cook, and constantly breaking down". Ayn Rand, for example, became addicted to Benzedrine and overuse led to mood swings, irritability, emotional outbursts, and paranoia. Even those taking modern prescription nootropics (such as Modafinil) often report high blood pressure/heart rate, anxiety, insomnia, impulsivity, nausea and addiction.

Where else can we see capacity gaps in more familiar situations? Let's look at situations where the focus is on **capacity** rather than knowledge and skills per se - related to your information processing capacity - how mentally sharp and efficient as well as focused and cognitively resilient you are.

- When you are in a work environment that is too complex and demanding for you to feel like you are picking things up at an adequate rate. Or when you feel like everyone else is working at a different functional level to you. As Jordan Peterson says,*"If you go into a job, and you're not smart enough for that job, you're going to have one bloody miserable time"*.

- When you are tired or burned out and you are not being efficient or accurate in your work: you have 'brain fog' and ideas are not flowing, mistakes are being made, and it's difficult to remain focused for long. This may be caused by tiredness through lack of sleep, overwork or accumulated burnout.

- When you are too stressed to function with clarity, fluidity and motivation - perhaps due to multiple deadlines, or concerns about performance & evaluation.

- When you need to comprehend or figure something out, but feel like what you need to grasp it is somewhat beyond you, no matter how much time you are investing in working through relevant material.

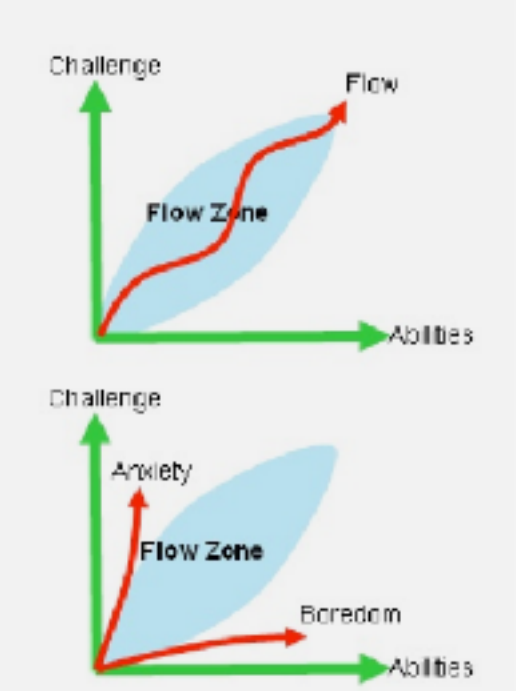
- When you are trying to convey an understanding of a subject matter you had previously reached to others, but you are struggling to communicate with any clarity.

- As you get older, you experience a general loss in speed, flexibility, clarity or mental stamina.

Psychological Flow

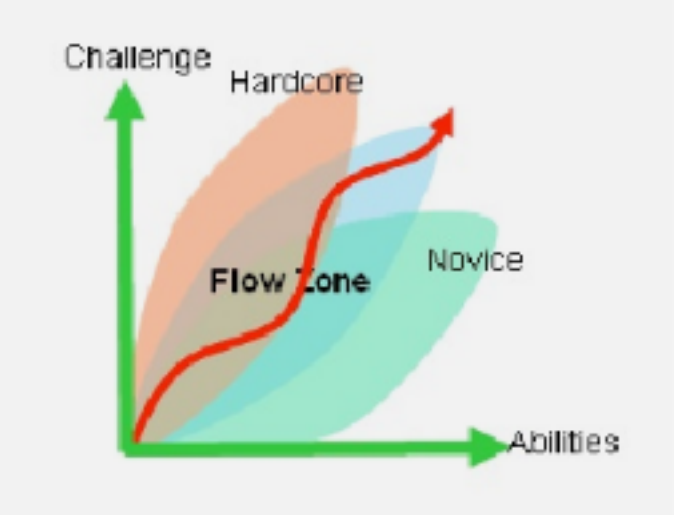
The inverse of not having enough capacity is having **too much** capacity. In these situations you will feel unchallenged, over-capable, and this can result in lack of motivation and boredom. It also doesn't allow for learning and capacity augmentation, since there needs to be a capacity gap to drive improvement.

The psychologist Mihaly Csikszentmihalyi gave us the theory of psychological **flow** to describe a state of optimal experience (Csikszentmihalyi, 1990). (1) In a state of flow, a person is engaged in a challenging task, working away, making progress with continuous reinforcing feedback, while being fully absorbed and lacking in self-consciousness.



Being in the 'flow zone' is the zone of **vectorized IQ** - where there can be optimal learning and cognitive capacity augmentation. With the right kind of structured training and experience you can tap into the flow zone to augment your IQ to increasing levels

of challenge - from ‘novice’ to ‘hardcore’ in the diagram here.



Getting feedback as you progress with your cognitive capacity is highly useful in this overall augmentation process. Assessing yourself with short fluid reasoning IQ tests is a great way to get the kind of feedback you need.

Extrinsic Motivation

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You also can use the cognitive tracking tests in two extrinsically motivating ways in the IQ Mindware programs.

0123 Sigma Rule

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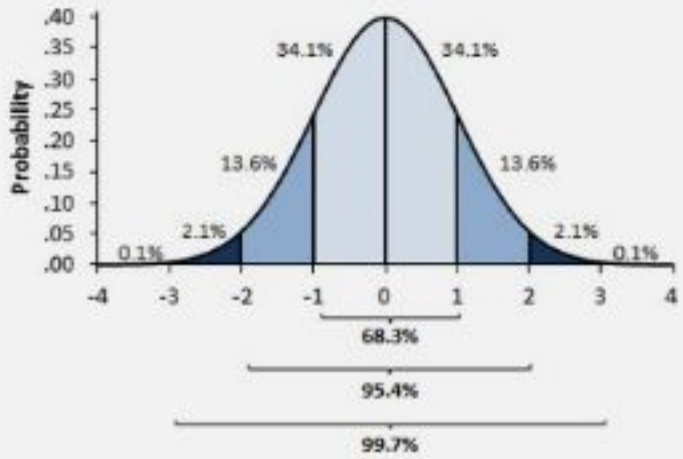
The first is to compare yourself to the general population using the bell curve, and see how your standardized score changes over time with training.

One of the most widely observed distributions of scores for any performance variable - whether IQ, chess playing, or sports performance - is the **normal distribution** or **bell curve**.

Scores on any bell curve be converted to standard deviation scores or **sigma scores**, as shown below.

It's always the case that about 68% of people in a bell curve are found between -1 and +1 sigma.

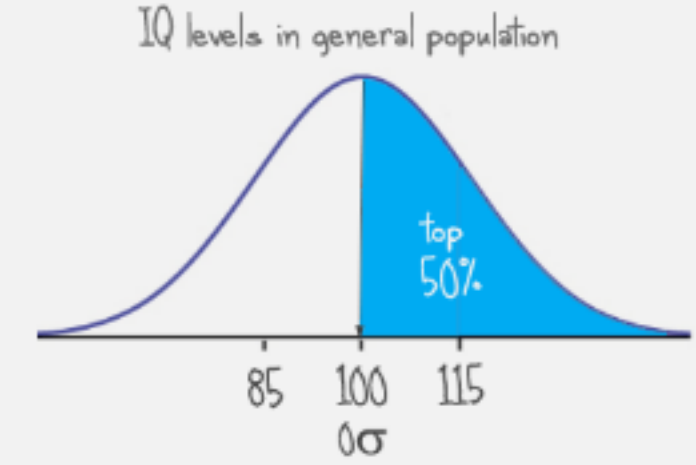


In the IQ bell curve, **1 sigma = 15 points** and the **average** score (0 sigma) is 100.

What is the 0123 Sigma Rule? This rule provides 4 objective benchmarks you can work with to track your progress, each of which has an intuitive, easy to use interpretation.

Above Average. 0 Sigma: The Top 50%

If you are higher than 0 sigma this puts you above 50% of the population – above average. This is a great benchmark.

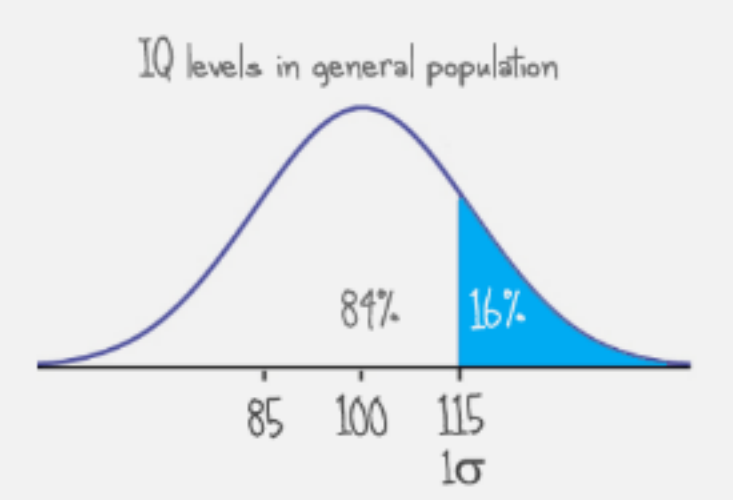


IQ Mindware brain training recommendation

If you have a pre-training IQ 10-20 points below 100, the 0 sigma level of 100, putting you in the top half of the population is an excellent goal.

Exceptional. 1 Sigma: The Top 16%

If you are more than 1 sigma from the average in the population this puts you above 84% of the population in the top 16%.



If you have an IQ of 115 (1 sigma) or above you are capable of the cognitive demands of almost any profession, and can attain the highest levels of education and training. An IQ above 115 is considered to be a **high IQ**.

The 'Smart Fraction'

The Smart Fraction Theory proposed by (2) tells us that national wealth is determined by the fraction of workers with an IQ equal to or greater than some minimum threshold. As we saw in Unit 4, IQ is a robust predictor of economic growth and productivity. According to the data, a 1 sigma IQ level of 115 places you above the smart fraction threshold.

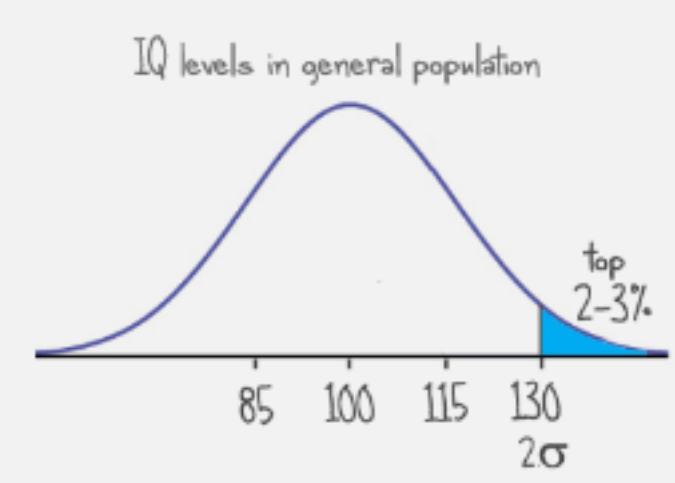
IQ Mindware Brain Training Recommendation

If you have a pre-training IQ below 115, the 1 sigma 'high IQ' level of 115 is an ideal target to train for.

Excellent. 2 Sigma: The Top 2-3%

This is a benchmark for becoming really elite. This is clean Ivy League university undergraduate level - the Harvards, Princetons & Oxbridges of the world.

For IQ, this is a level of 130 or more. This is around Mensa standard. To become a Mensan, you need to demonstrate you have an IQ in the top two per cent – the 98th percentile. There is no other criteria. This is a 1 in 50 level of cognitive ability.



IQ Mindware brain training recommendation

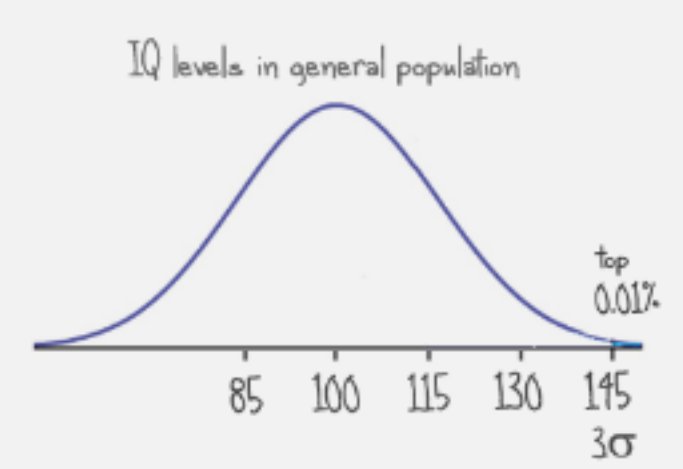
If you have a pre-training IQ of between 115 and 125, the 2 sigma level of 130 (Mensa level) is an ideal target to train for.

Off The Curve. 3 Sigma: Top 0.1%

This is an IQ of 145 or higher. This level of cognitive performance puts you at a national level.

In a high school of 1000 students, only 1 student may have IQs of this level. How this - in practice - may be distinguished from someone with an IQ at the 2 sigma level would be difficult to determine. Jordan Peterson (rather fancifully) claims:

"If you want to be the best at what you are doing, bar none, then having an IQ of above 145 is a necessity".



IQ Mindware brain training recommendation

If you have a pre-training IQ of between 130-140 the 3 sigma level of 145 (cognitive elite) is an ideal target to train for.

> One thing I have learned as a competitor is that there is a clear distinction between what it takes to be decent, what it takes to be good, what it takes to be great and what it takes to be among the best...
>
> -Josh Waitzkin,

123 Sigma Rule Summary

In summary, the 0123 Sigma Rule is a rule that says that meaningful and measurable benchmarks for your vectorized IQ can be pegged to 0 sigma (above average), 1 sigma (exceptional), 2 sigma (elite) and 3 sigma (off the curve) levels – and that these levels

encompass the full range of excellence for intelligence.

At IQ Mindware we are not fixated on tests and self-quantification. What's important is what you do with your precious cognitive resources, tapping into the cognitive flow zone and setting motivating targets, getting useful feedback in the learning process.

Equivalent School Years

Another measure you can use as you chart gains in your IQ is by 'school years'. As we saw in Unit 6, IQ levels can change dramatically over a lifetime. Formal education plays an important role here. A year of schooling gives students new knowledge, but it also equates with an average of over 3 IQ points according to a systematic meta-analysis published in *Psychological Science*. (3) The research team analysed 42 data sets from 28 studies collected from a total of 615,812 individuals.

The researchers found that an additional year of education was associated with an increase in IQ that ranged from 1.197 IQ points to 5.229 IQ points, with an average increase of 3.394 IQ points.

"*The most surprising thing was how long-lasting the effects seemed to be, appearing even for people who completed intelligence tests in their 70s and 80s,"* says psychological scientist Stuart J. Ritchie of the University of Edinburgh. *"Something about that educational boost seemed to be beneficial right across the lifespan."*

So let's use a round number and call a **3 point IQ gain** an equivalent school year.

You can now interpret any IQ gains in school year terms. If you make a gain of 12 IQ points in 10 hours of brain training that is equivalent to 4 school years.

Vectorizing Your IQ Summary

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With this Ebook I have provided: (1) An educational resource, explaining IQ, g and the dynamic nature of general intelligence from a scientifically informed point of view. (2) A motivational resource, in which I reviewed evidence for the value of IQ, the kind of IQ brain training that works, and the magnitude of IQ increase you can expect from your training.

Visit www.iqmindware.com to take up the challenge.

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