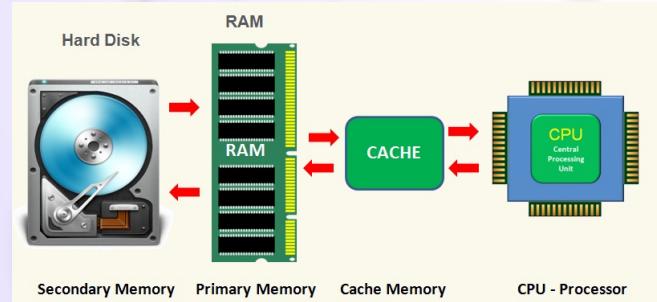


Thinking, Control, Intelligence

Randall C. O'Reilly

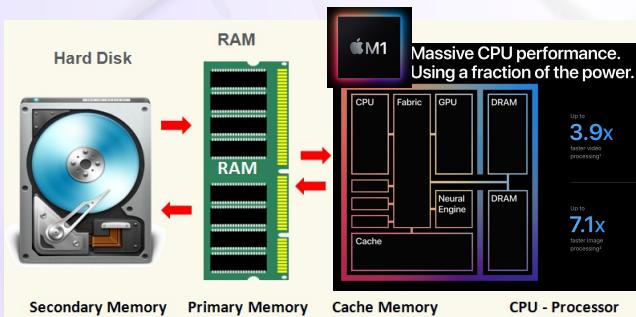
What is Smart?



It is easy to identify what makes a computer smarter:

- * Faster
- * More memory

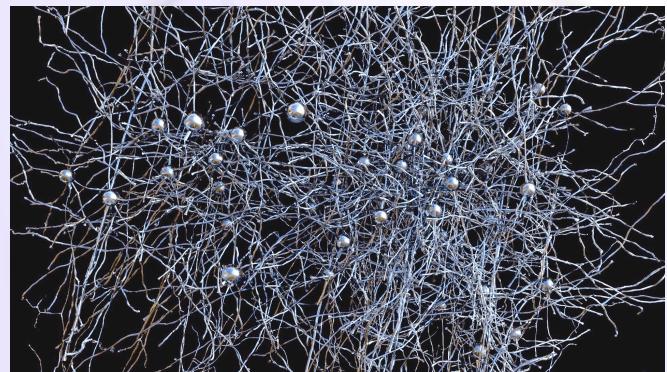
What is Smart?



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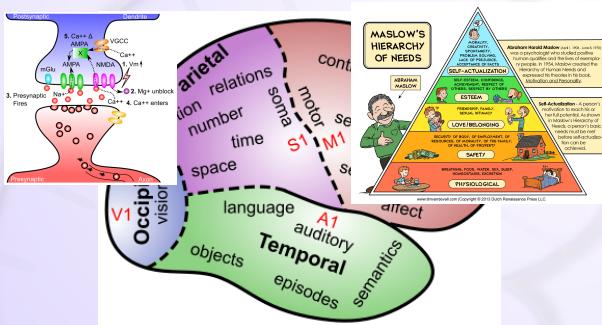
- * Faster
- * More memory

But what about the brain?



Do smarter people have more neurons? More synapses?
We actually *lose* synapses over development..

But what about the brain?



Most of what we can do, we learn, and learning is driven by motivation..



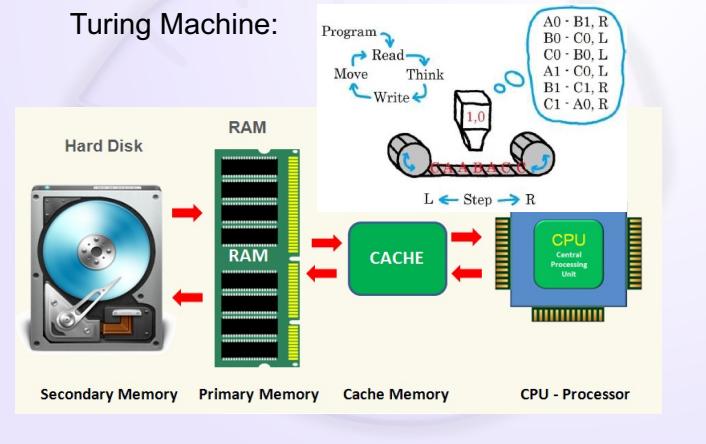
What is “Thinking”?



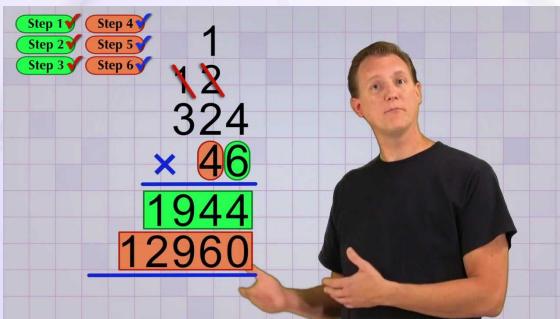
- * Conscious manipulation of knowledge
- * Takes time, and concentration: multi-step
- * Focused on solving problems

Information Processing: CPU

Turing Machine:



Algorithm



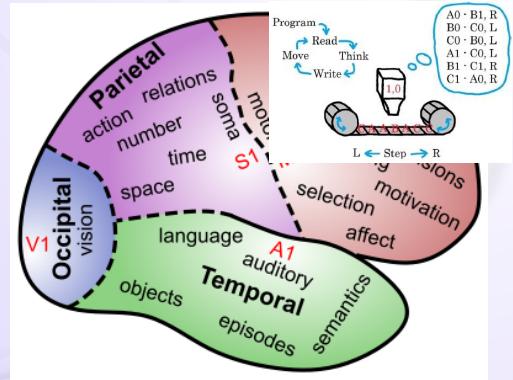
Precise set of step-by-step operations to perform, to process information: take input, do computation, produce output..

Neural CPU = Turing Machine

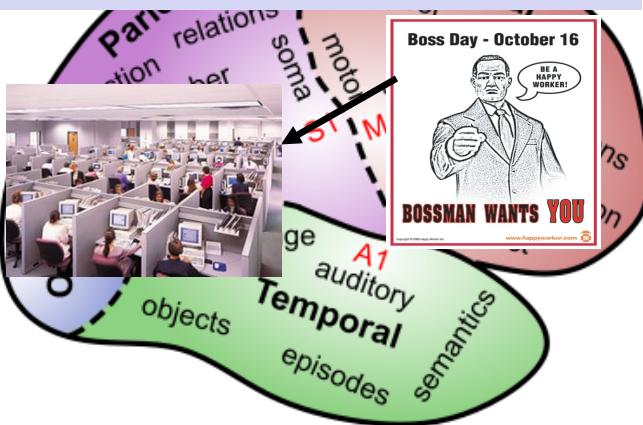
Program: actual human language (e.g., English): talk yourself through it..

Active memory: prefrontal cortex working memory

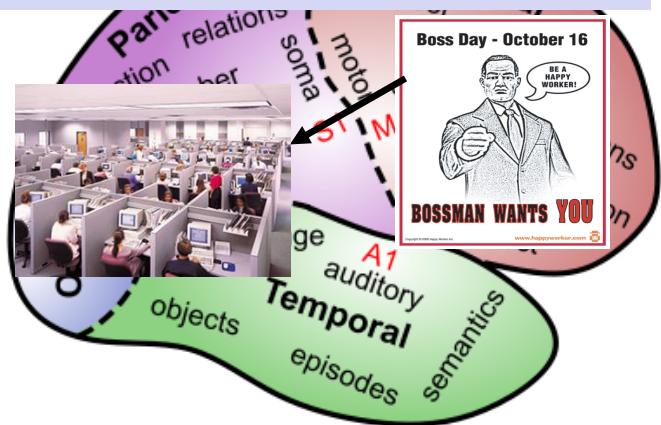
Memory storage and retrieval (tape): hippocampal memory system (or a piece of paper!)



PFC = Control, Working Memory



PFC = Top-Down Biasing



Stroop Task: Top Down Biasing

RED

Stroop Task: Top Down Biasing

GREEN

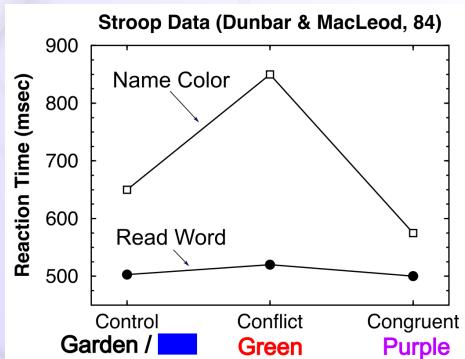
Stroop Task: Top Down Biasing

RED

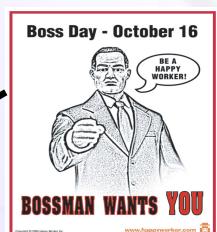
Stroop Task: Top Down Biasing

GREEN

Reading is *Automatic*
Color Naming needs *Control*



Key Idea: Top-Down Biasing



"Name colors you idiots!"

"But we prefer reading
(Facebook..)"

System 1, 2 (Kahneman)

System 1: posterior cortex – *domain-specific* knowledge and *fast* processing

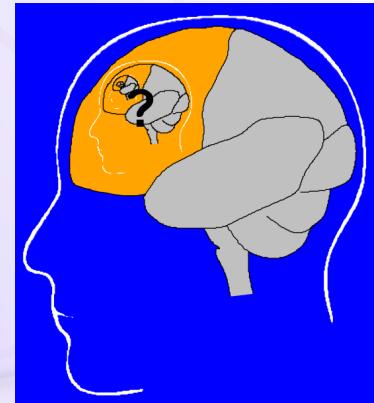
Previously known as **automatic processing**

System 2: prefrontal cortex – general purpose cognitive processing and problem solving (slow)

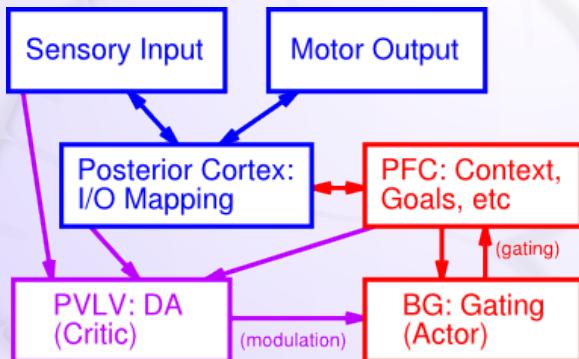
Previously known as **controlled processing**

(It takes a Nobel prize to reinvent a well-established distinction, using much worse terms!)

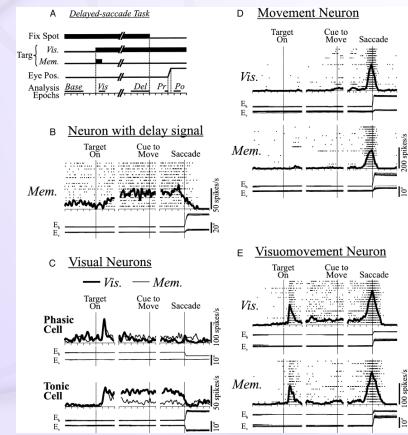
The Homunculus Problem



It Takes a Network..



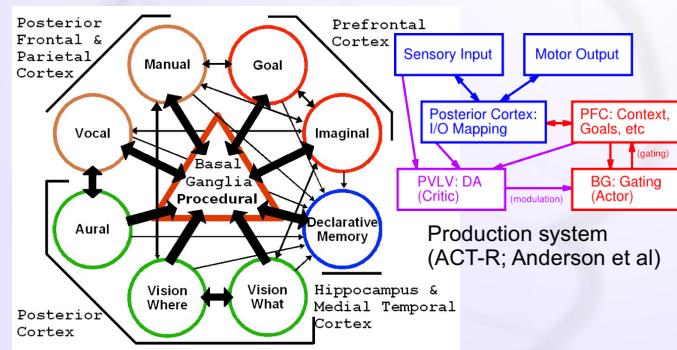
PFC Does Active Maintenance



Active Maintenance Can Do it All

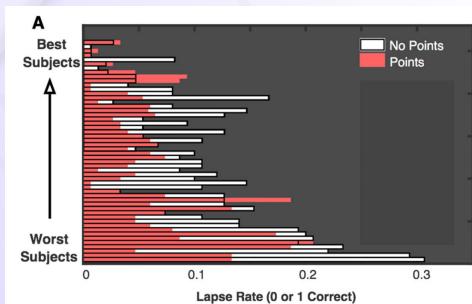
- Cognitive Control
 - Maintained activity drives top-down biasing
- Planning
 - Think about things that are not there (future)
- Motivation
 - Maintain goals
- Reward processing
 - Maintain possible outcomes
- Decision making
 - Maintain alternatives

Basal Ganglia Controls Program Flow



Motivation and Working Memory

(Adam & Vogel, 2016)



Raw "MAX" working memory capacity does NOT differ between subjects
What DOES differ is rate of tuning out / lapsing!
Miyake: Class grades predicted by mind-wandering, procrastination!

More Dichotomies

System 1 = Automatic = **Crystallized Intelligence**
= posterior cortex with well-tuned synapses over a lifetime of experience (wise..)

System 2 = Controlled = **Fluid Intelligence** =
prefrontal cortex & basal ganglia with strong ability to rapidly update and maintain information in *working memory*

Wason Card Selection



Cards have number on one side, color on other.

You need to test whether the following rule is true:

If there is an even number on one side, then the other side is red. Which to turn over?

Brain Loves Concrete, not Abstract



Rule: If you are drinking alcohol, you must be over 21. Who do you card?

Cognitive Biases, Heuristics

We use simple, concrete, shortcuts to reason, instead of complicated logic, statistics

Heuristic: shortcuts, "rule of thumb"

Availability Heuristic

Whatever comes to mind, go with that! Much easier than figuring out the actual statistics!

- Problem: not very accurate..

What is Greatest Risk?

- A. Nephritis, nephrotic syndrome, nephrosis
- B. Airplane crash

Actual Stats:

<http://www.cdc.gov/nchs/fastats/leading-causes-of-death.htm>

Cause	Number	%	Rate per 100,000
... All causes	2,596,993	100.0	821.5
1 Diseases of heart	611,105	23.5	193.3
2 Cancer	584,881	22.5	185.0
3 Chronic lower respiratory	149,205	5.7	47.2
4 Accidents	130,557	5.0	41.3
5 Cerebrovascular diseases	128,978	5.0	40.8
6 Alzheimer's disease	84,767	3.3	26.8
7 Diabetes mellitus	75,578	2.9	23.9
8 Influenza and pneumonia	56,979	2.2	18.0
9 Nephritis, etc	47,112	1.8	14.9
10 Suicide	41,149	1.6	13.0
... Airplane crashes	59		

Representative Heuristic

Compare how similar to a **prototypical** case

- Problem: tend to ignore **base rates**.
- And rely on **stereotypes**

Linda..

Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

Which is more probable?

- A. Linda is a bank teller.
- B. Linda is a bank teller and is active in the feminist movement.

Confirmation Bias CCC = Control!

Only pay attention to information consistent with our preexisting beliefs!

- Astrology, politics, .. Everywhere!
- *Filter bubble* = more and more of a problem in modern digital media!
- **Belief Persistence**: just plain ignore / discredit inconsistent information!

Why? Our beliefs are central to our feeling of control and identity: challenge is very threatening!

Gambler's Fallacy

Belief that: If you've just been losing, you're more likely to win! (Or vice-versa)

But, probability of heads is *always* 50% no matter how many heads or tails have come before!

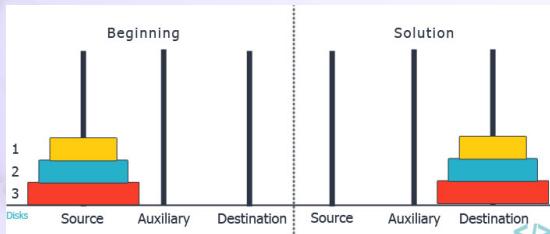
Interestingly: probability *over time* of HH vs HT is *NOT* the same!! This is likely basis of this fallacy.

<https://www.pnas.org/content/early/2015/03/05/1422036112>

Problem Solving

Trial and Error: try and see what works..

Hill climbing: make current state closer to target state – doesn't always work though!



Thinking Outside the Box



Connect all of the dots using only 4 straight lines, without lifting up 'pen':

Mental set, functional fixedness: inside the box...

Who is Smart?



WRITTEN BY
Thomas Oppong

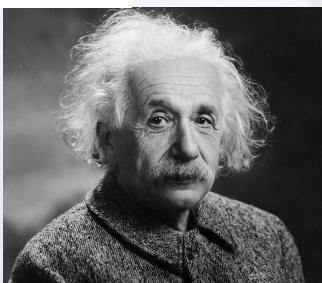
Founder @AllTopStartups | Featured at Forbes, Business Insider, etc. | Join my personal newsletter for life and career tools at <https://postanly.substack.com>

Genius Takes Time And Extraordinary Effort

Buckminster Fuller said, "I'm not a genius. I'm just a tremendous bundle of experience."

Mozart had clocked up 3500 hours by the time he was 6 and had studied his chosen profession for 18 years before he wrote his Piano Concerto No 9 at the age of 21.

Tiger Woods started when he was 2 years old. Serena Williams started playing at 3, Venus Williams at 4. They committed to deep, sustained immersion in purposeful practice.



IQ Scales and History

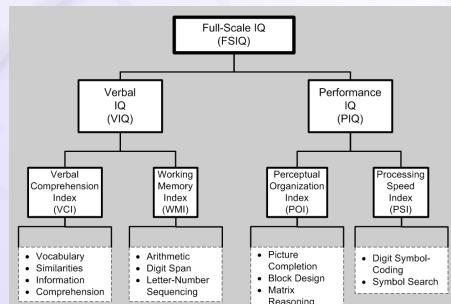
Stanford-Binet: first IQ test (Alfred Binet)

WAIS-III: Wechsler Adult Intelligence Scale: first IQ test for adults

Spearman: Indifference of the Indicator: "smart" people do well on any test: **g = general IQ factor**



WAIS

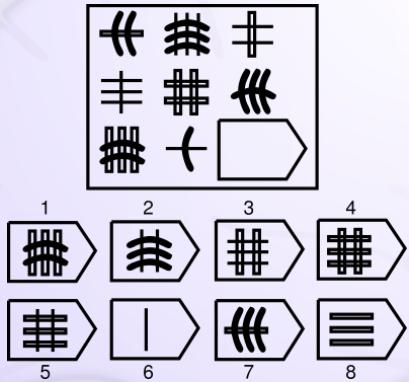


Standardized: 100 = average

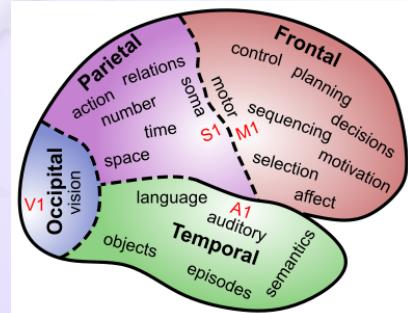
Reliability: test-retest

Predictive validity: IQ is *single* best predictor of grades, SAT tests, educational outcomes. Correlated with health. But not best predictor of job performance.

g = Raven's Progressive Matrices



Multiple Intelligences



Thinking is located in every single synapse in the brain

There are as many different kinds of thinking as there ⁴⁴ are neurons and synapses and brain areas...

Multiple Intelligences

Sternberg: **Triarchic** = analytic, creative, practical

Carroll: **Three-stratum** (g , 8 more specific, and then 69 even more specific)

Fluid intelligence (Gf = PFC, g) vs. **Crystallized** (Ge = posterior cortex, knowledge, wisdom)