Cognitive Psychology

http://compcogscisydney.org/psyc2071/

A/Prof Danielle Navarro
d.navarro@unsw.edu.au
compcogscisydney.org

Research interests: human learning, reasoning, induction, decision making, computational modelling, statistics

Close your eyes and imagine flipping a fair coin 5 times in a row… and remember the outcomes

(yes, I know you have the slides and can jump ahead, but why break the demo?)

There are 32 possible responses, each of which should be equally likely, right?

TTTTT	HHHHH	THTTT	HTHHH
TTTTH	HHHHT	THTTH	HTHHT
TTTHT	HHHTH	THTHT	HTHTH
TTTHH	HHHTT	THTHH	HTHTT
TTHTT	HHTHH	THHTT	HTTHH
TTHTH	HHTHT	THHTH	HTTHT
TTHHT	HHTTH	THHHT	HTTTH
TTHHH	HHTTT	THHHH	HTTTT

Did you pick one of these?

		THTTT	HTHHH
TTTTH	HHHHT		
TTTHT	HHHTH	THTHT	HTHTH
TTTHH	HHHTT		
TTHTT	HHTHH		
TTHHH	HHTTT	THHHH	HTTTT

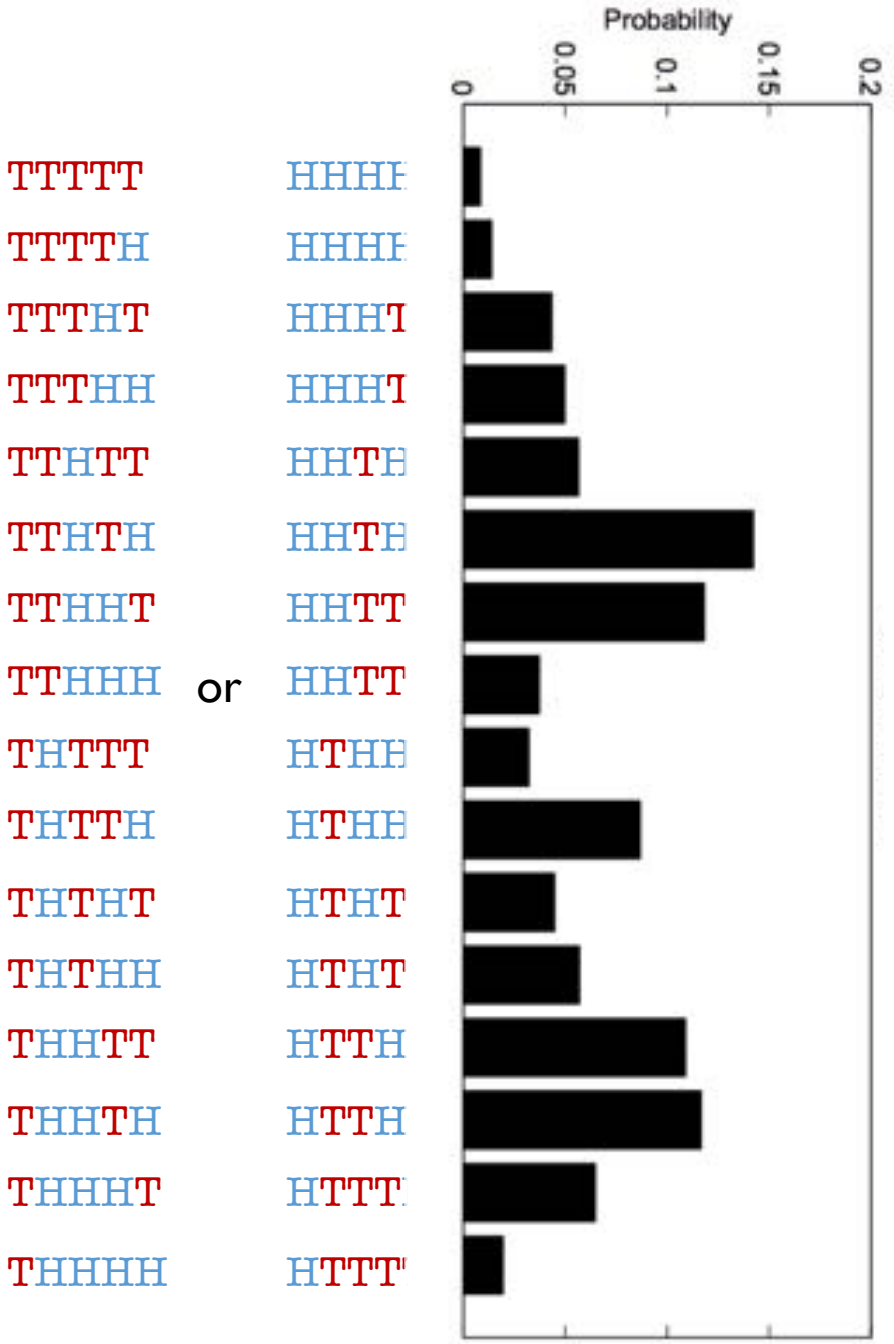
How about these?

		THTTH	HTHHT
		THTHH	HTHTT
		THHTT	HTTHH
TTHTH	HHTHT	THHTH	HTTHT
TTHHT	HHTTH	THHHT	HTTTH

How many people picked one of these?

TTTTT HHHHH

… and did you do this because you thought it was a trick question?

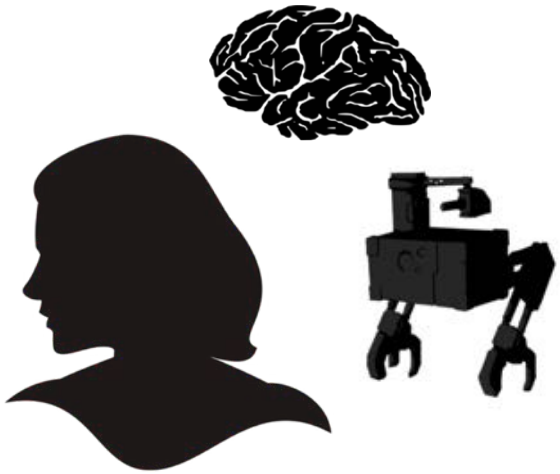


Zenith radio data: 20,099 people calling into a radio station to test their psychic powers by predicting a random sequence of outcomes

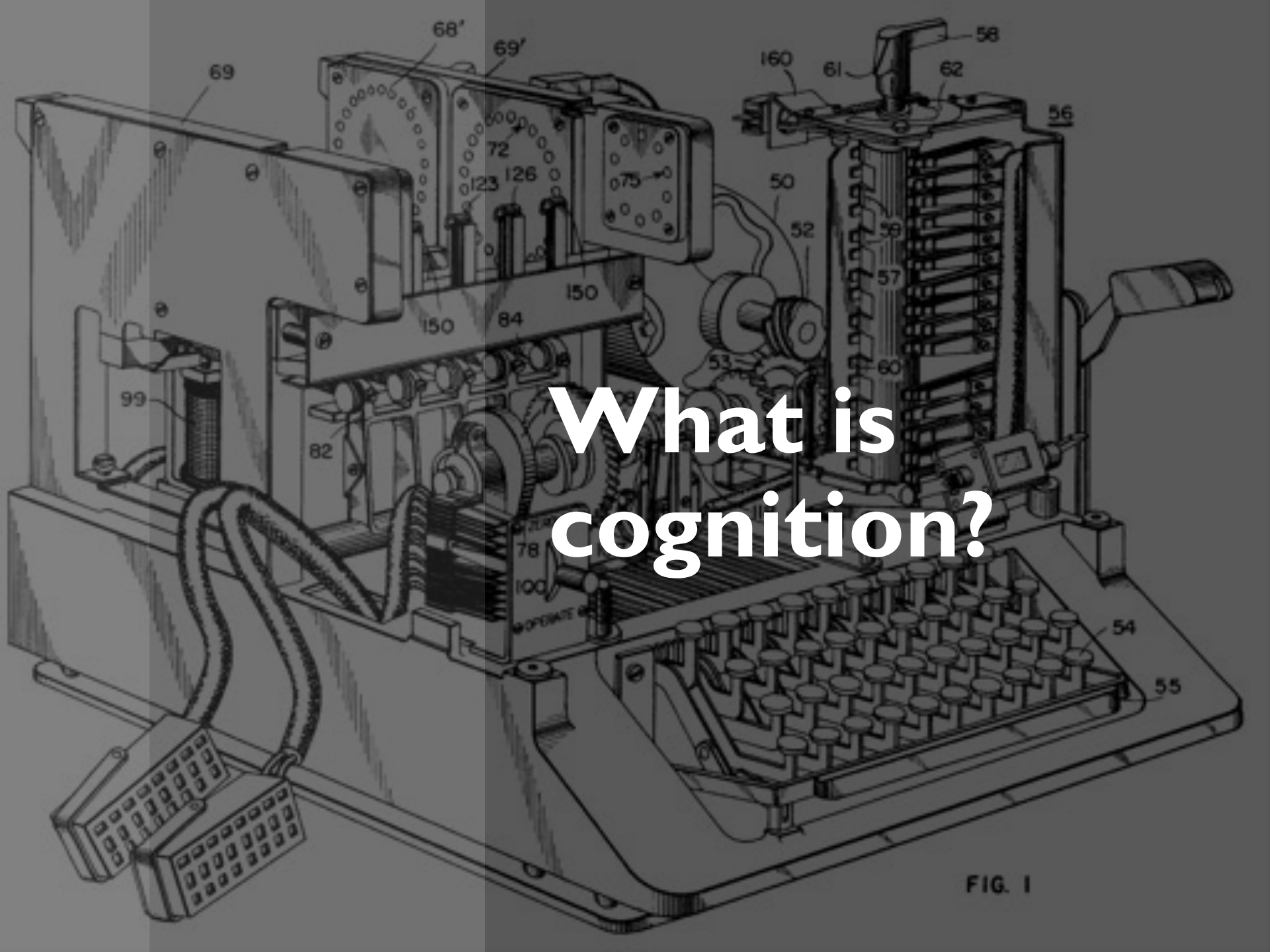
Goodfellow (1938)

Cognitive Psychology

- Part 1: Navarro
  - L1: Introduction
  - L2: Attention
  - L3: Similarity
  - L4: Reasoning
  - L5: A case study
  - L6: Q&A, recap, etc



- Part 2: Taft
  - Propositional knowledge, semantics, lexical decisions, memory, etc



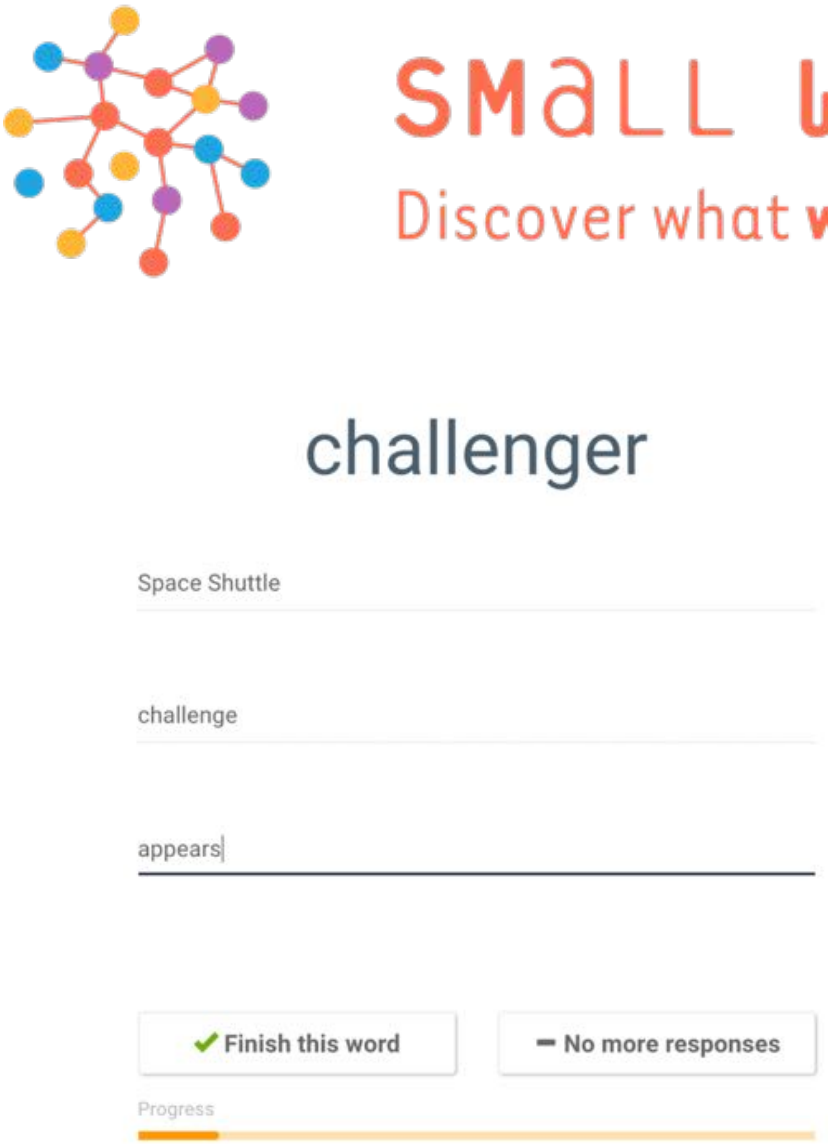
What is cognition?

"You shall know a word by the company it keeps"

- John Firth, 1957

small world of words

Discover what **words** mean for **people** worldwide



The "Small World of Words" English word association norms for over 12,000 cue words.

Simon De Deyne[1], Danielle J. Navarro[2], Amy Perfors[1], Marc Brysbaert[3], and Gert Storms[4]

[1]University of Melbourne, School of Psychological Sciences, 3010 VIC, Australia
[2]University of New South Wales, School of Psychology, 2052 NSW, Australia
[3]Ghent University, Department of Psychology, 9000 Ghent, Belgium
[4]KU Leuven, Department of Psychology, 3000 Leuven, Belgium

Abstract

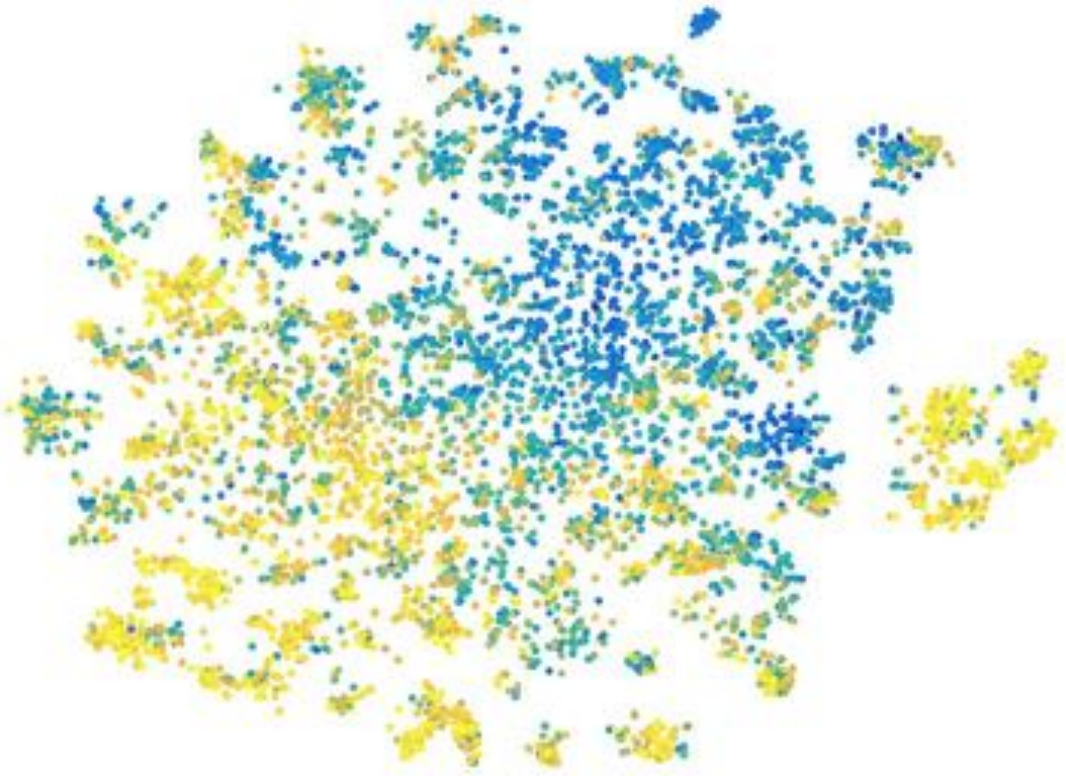
Word associations have been used widely in psychology, but the validity of their application strongly depends on the number of cues included in the study and the extent to which they probe all associations known by an individual. In this work, we address both issues by introducing a new English word association dataset. We describe the collection of word associations for over 12,000 cue words, currently the largest such English-language resource in the world. Our procedure allowed subjects to provide multiple responses for each cue, which permits us to measure weak associations. We evaluate the utility of the dataset in several different contexts, including lexical decision and semantic categorization. We also show that measures based on a mechanism of spreading activation derived from this new resource are highly predictive of direct judgments of similarity. Finally, a comparison with existing English word association sets further highlights systematic improvements provided through these new norms.

Keywords: Word associations, mental lexicon, networks, similarity, spreading activation

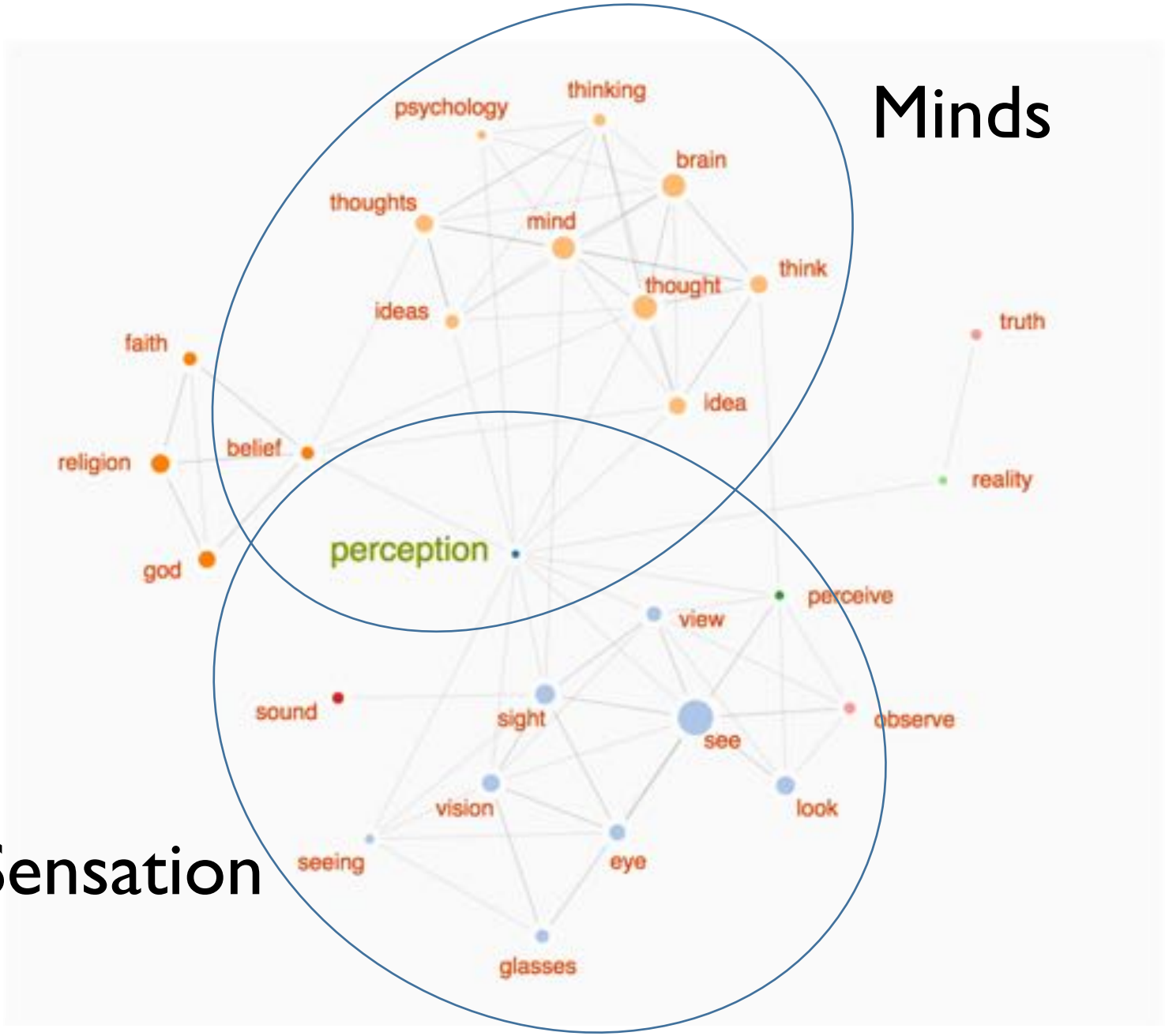
https://smallworldofwords.org/en/project/home

small world of words

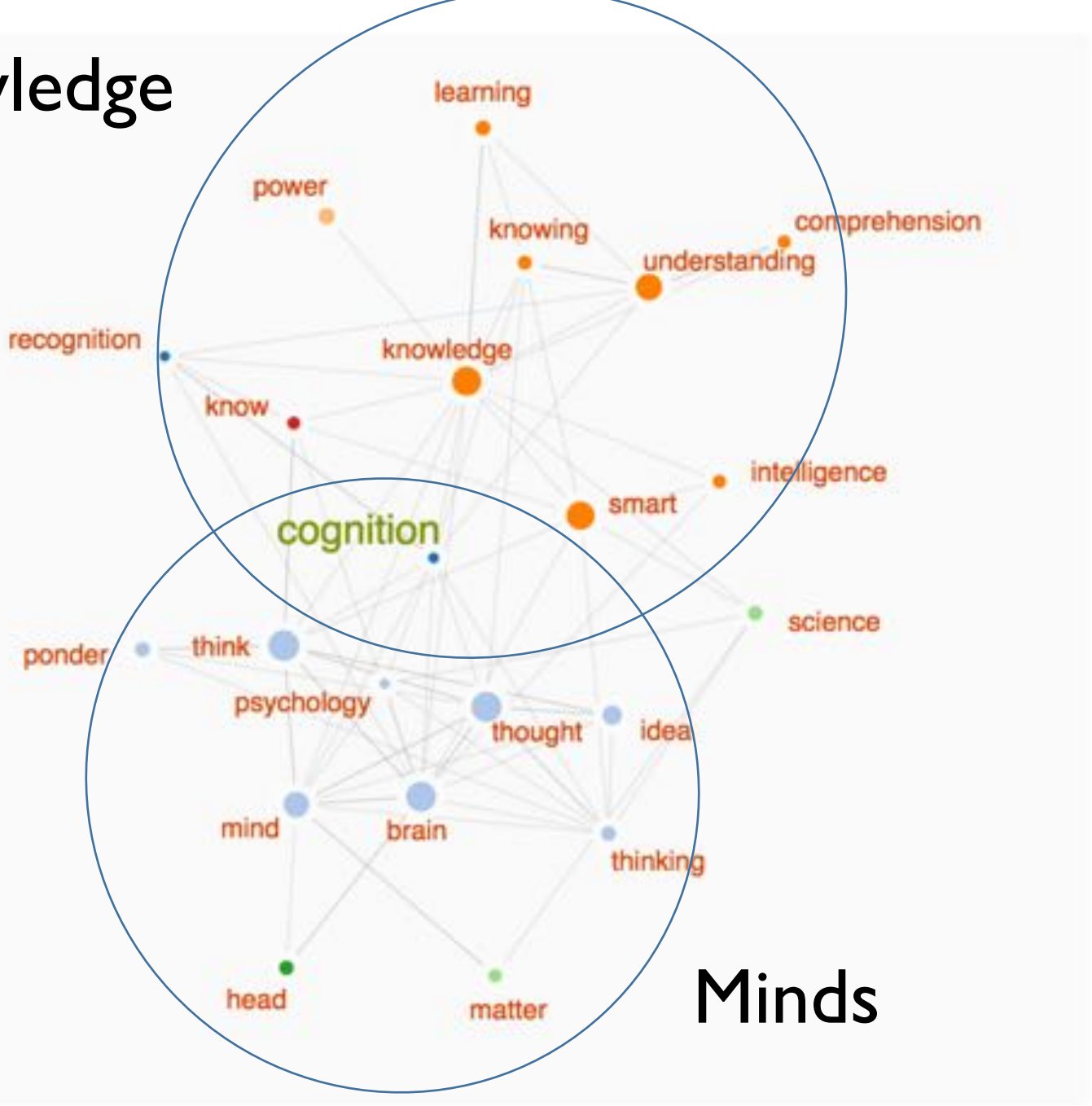
Discover what **words** mean for **people** worldwide



https://smallworldofwords.org/en/project/home


Minds
Sensation
psychology
thinking
brain
thoughts
mind
think
thought
ideas
truth
faith
idea
religion
belief
reality
perception
god
perceive
view
sound
sight
observe
see
vision
look
seeing
eye
glasses

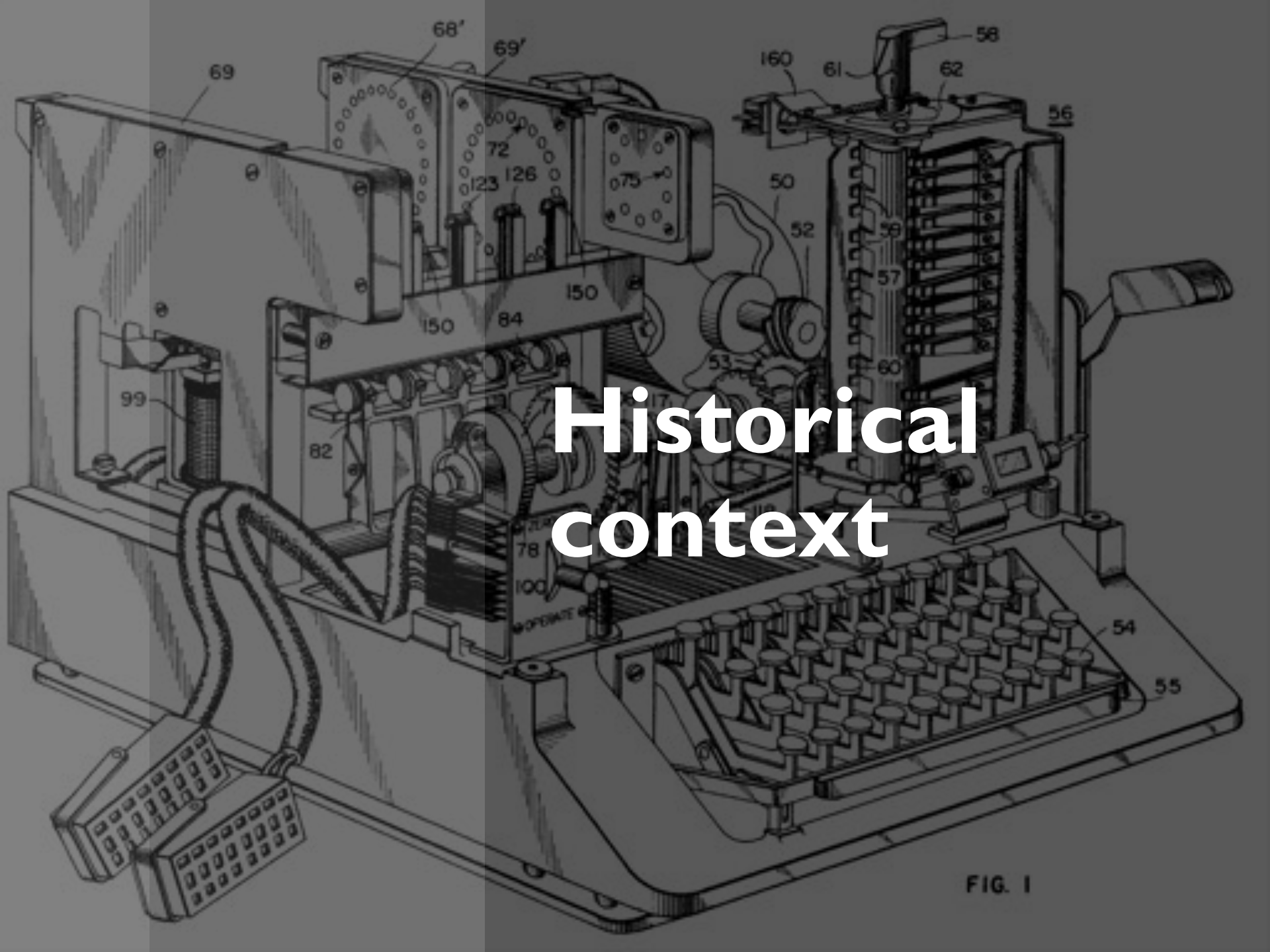
Knowledge



Minds

Perception is concerned with how the mind interprets sensory data

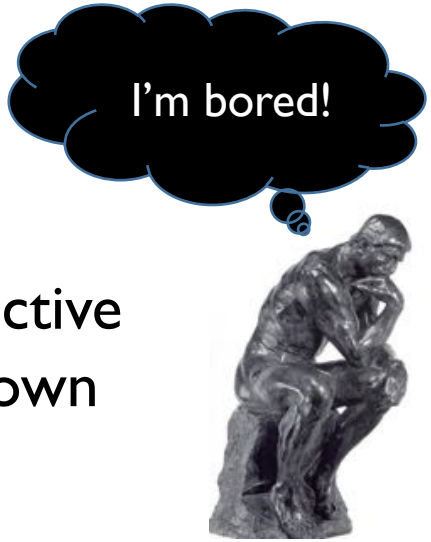
Cognition is concerned with knowledge, reasoning, memory, language, decision making, etc



Historical context

Wilhelm Wundt

Founded the first experimental psychology lab in 1897 at the University of Leipzig



Used the method of introspection… subjective observation of one's own experiences

Behaviourist critique

"Psychology as the behaviorist views it is a purely objective experimental branch of natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no essential part of its methods, nor is the scientific value of its data dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness. The behaviorist, in his efforts to get a unitary scheme of animal response, recognizes no dividing line between man and brute."

- John Watson, 1913, "Psychology as a behaviorist views it"

Behaviourist principles

- *Methodological*: Psychological theories should be based on observable empirical data

  "…psychology as a behaviorist views it is a purely objective experimental branch of natural science. Its theoretical goal is … prediction and control" (Watson, 1913, p. 158).

- *Theoretical*: Behaviour is best understood in terms of stimulus-response associations.

  "[The aim of Behaviorism is…] To predict, given the stimulus, what reaction will take place; or, given the reaction, state what the situation or stimulus is that has caused the reaction" (Watson, 1930, p. 11).

The latter is now commonly referred to as ***"Radical Behaviorism"***

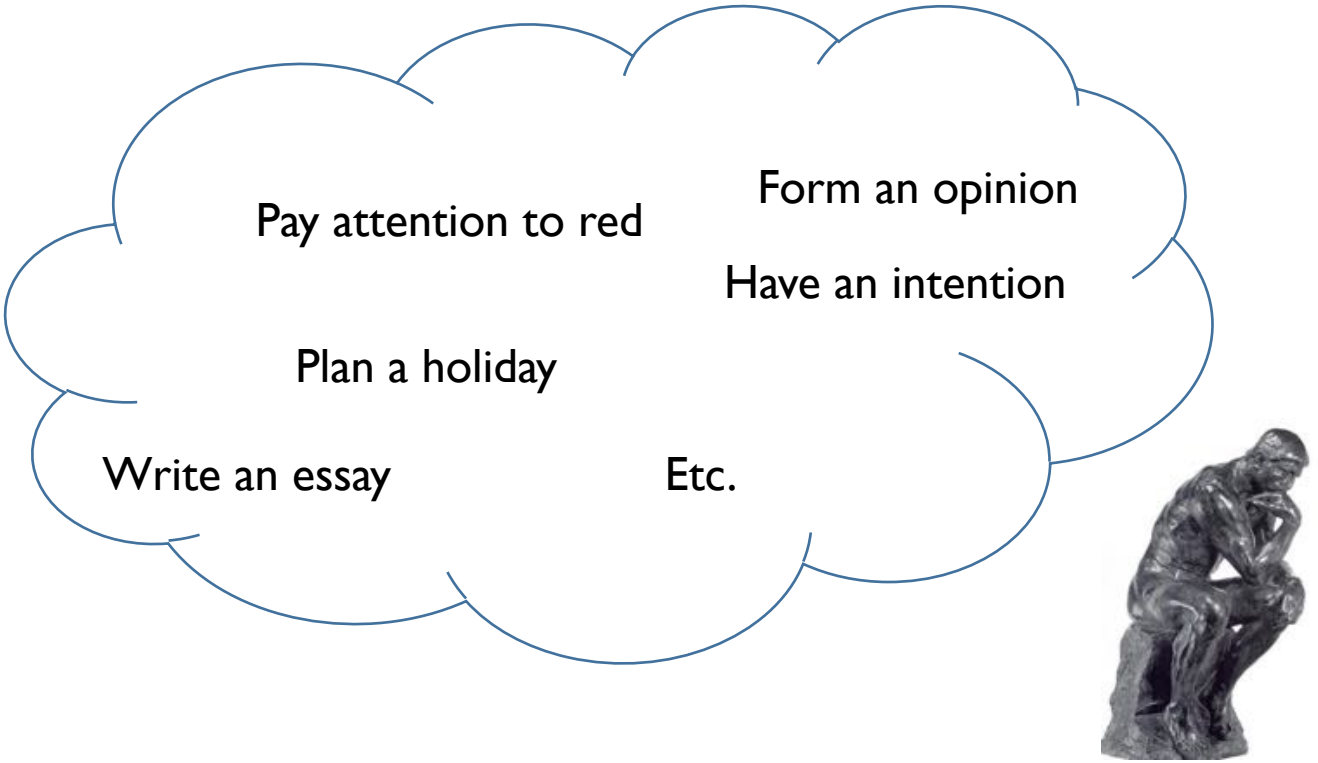
Behaviourist successes

- New methods & practices
- An understanding developed of how animals (and humans) learn certain new behaviours. i.e. *conditioning*
- Psychological theories became testable and falsifiable.
- Huge implications for the clinic

Skinner and "his box"

Limits of (radical) behaviourism

- S-R contingencies impose very strong constraints
- Hard to study these…



Example – language production

- Language has "non-adjacent dependencies"… very hard to describe in terms of S-R contingencies

The car that I saw yesterday is yellow

The cars that I saw yesterday are yellow

Constraint

Chomsky's scathing review of Skinner's *Verbal Behavior* was influential

- "Markov chain" models of language that produce text by chaining together S-R contingencies are pretty hilarious…

Example – language production

"Come, Darcy," said he, "I must have you dance. I hate to see you standing about by yourself in this stupid manner. You had much better dance."

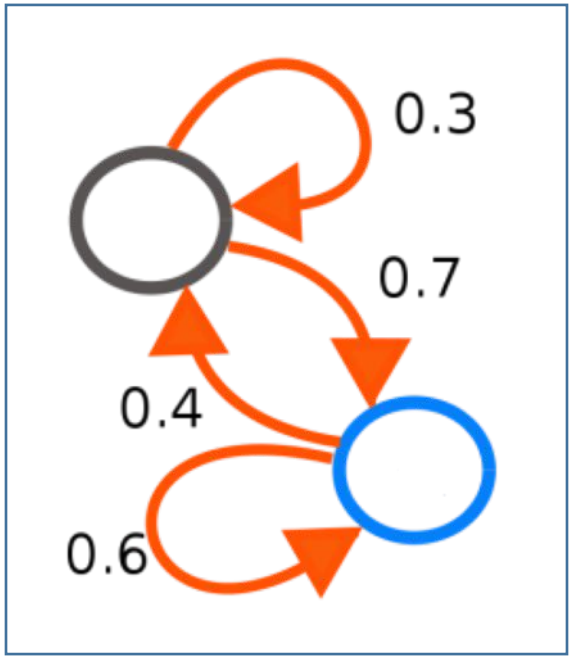
"I certainly shall not. You know how I detest it, unless I am particularly acquainted with my partner. At such an assembly as this it would be insupportable. Your sisters are engaged, and there is not another woman in the room whom it would not be a punishment to me to stand up with."

- Jane Austen, *Pride & Prejudice*

Example – language production

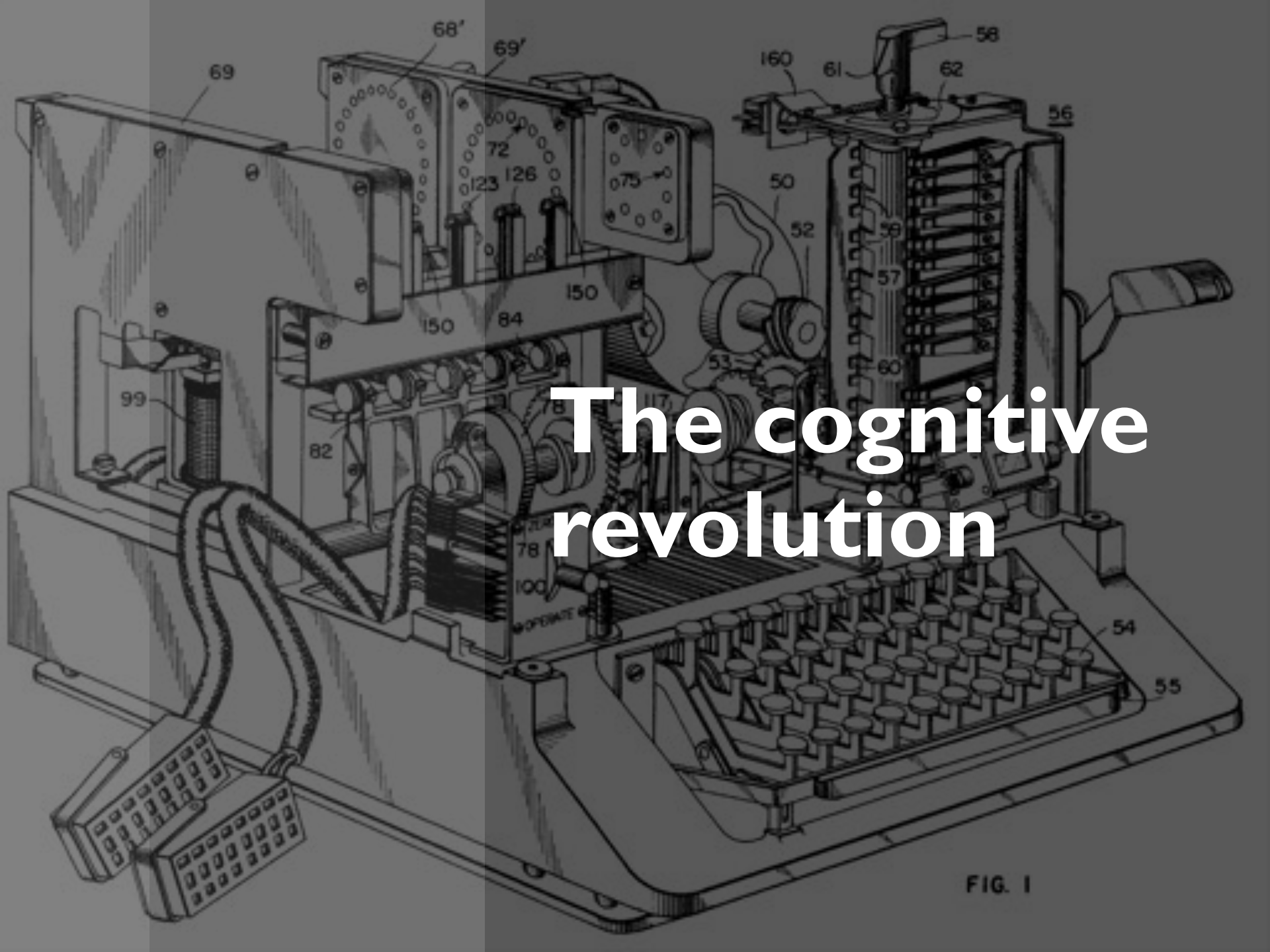
"Come, Darcy," said he, "I must have
occasion to write in the opposite corner,
saw it all with great intrepidity: "Miss
Elizabeth Bennet."

"Miss Elizabeth Bennet!" repeated Miss
Bingley. "I am not particularly speaking of
such a man really is by the possessor, and
often without any attention to herself, she
was welcomed by her sister allowed it to
you? Mr. Robinson's asking him how he liked
our Meryton assemblies, and that you are
the youngest, I'm the tallest."



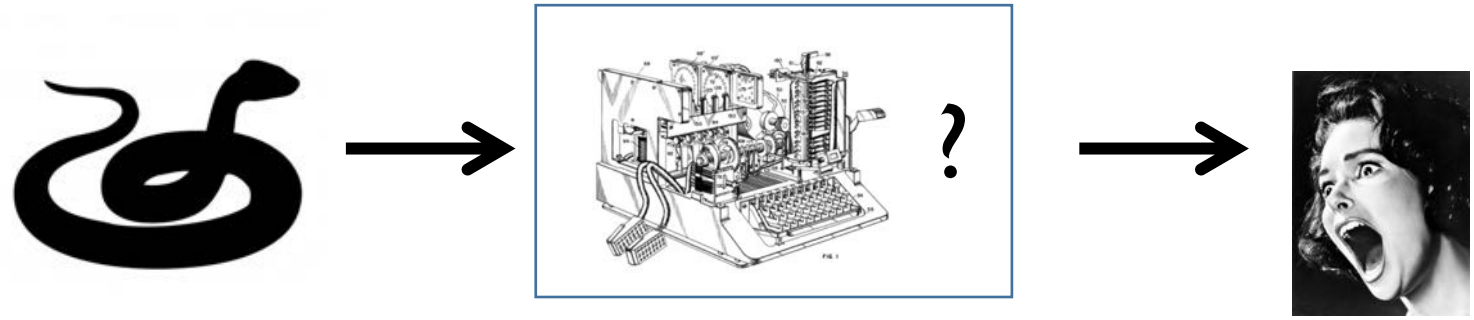
- A simple "response chaining" model
trained on *Pride and Prejudice*

https://ermarian.net/services/converters/markov/words



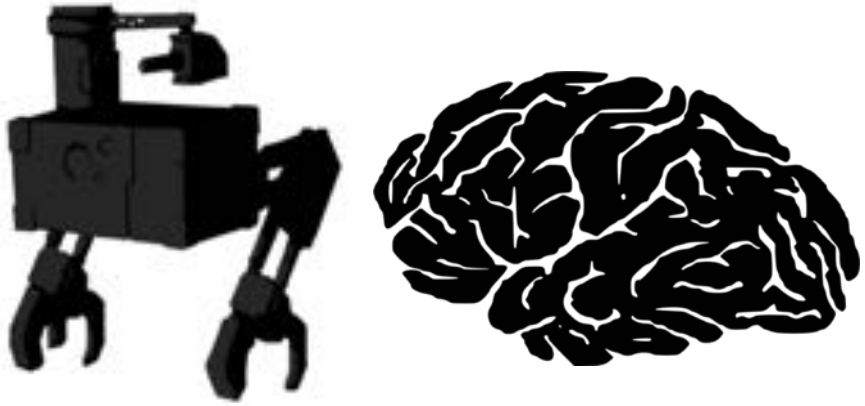
The cognitive revolution

(Radical) behaviourism ... the contents of mind are unobservable therefore off-limits to science



Cognitivism … the mind is a kind of unknown biological machine, and scientists may propose theories about its structure

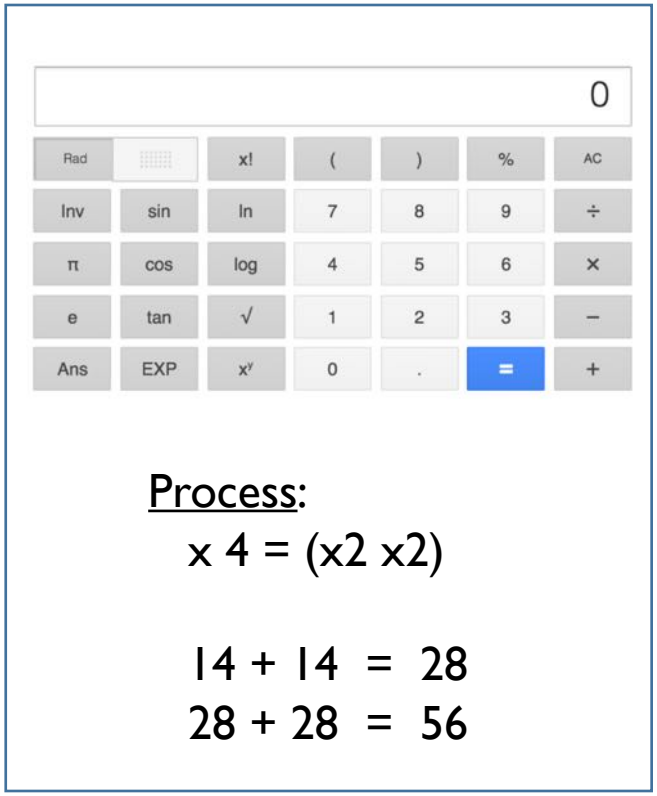
What kind of machine is a mind?
The computational metaphor



Information processing machines

Stimulus:

14 x 4



Process:

x 4 = (x2 x2)

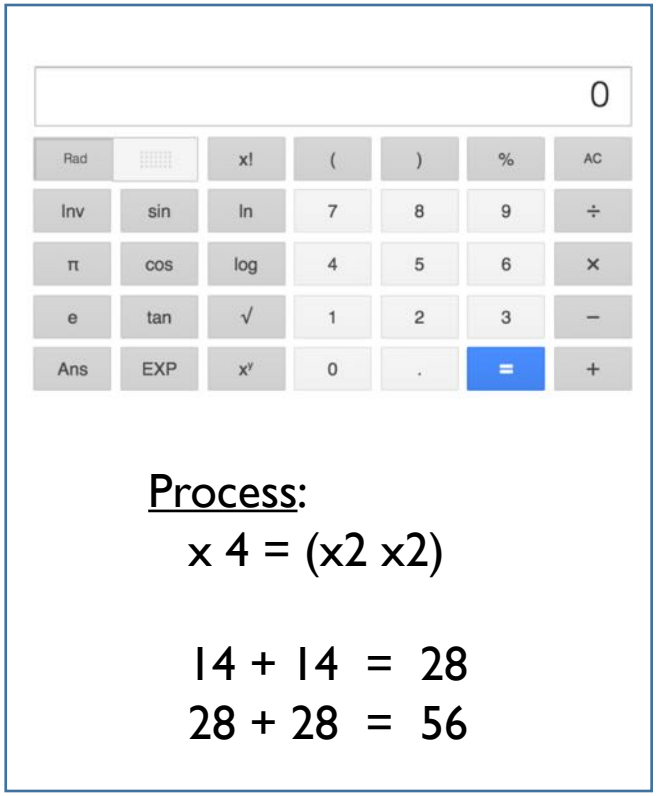
14 + 14 = 28

28 + 28 = 56

Response:

56

Empirically testable predictions?



Process:

x 4 = (x2 x2)

14 + 14 = 28

28 + 28 = 56

Speed?

x6 should take longer to perform than x4

Accuracy?

If each step is noisy we should also see more errors

Cognitive psychology as a computationalist views it

- "*Information processing*"
  - The computational metaphor suggests that we can use the language of "*computing*" to build "models"

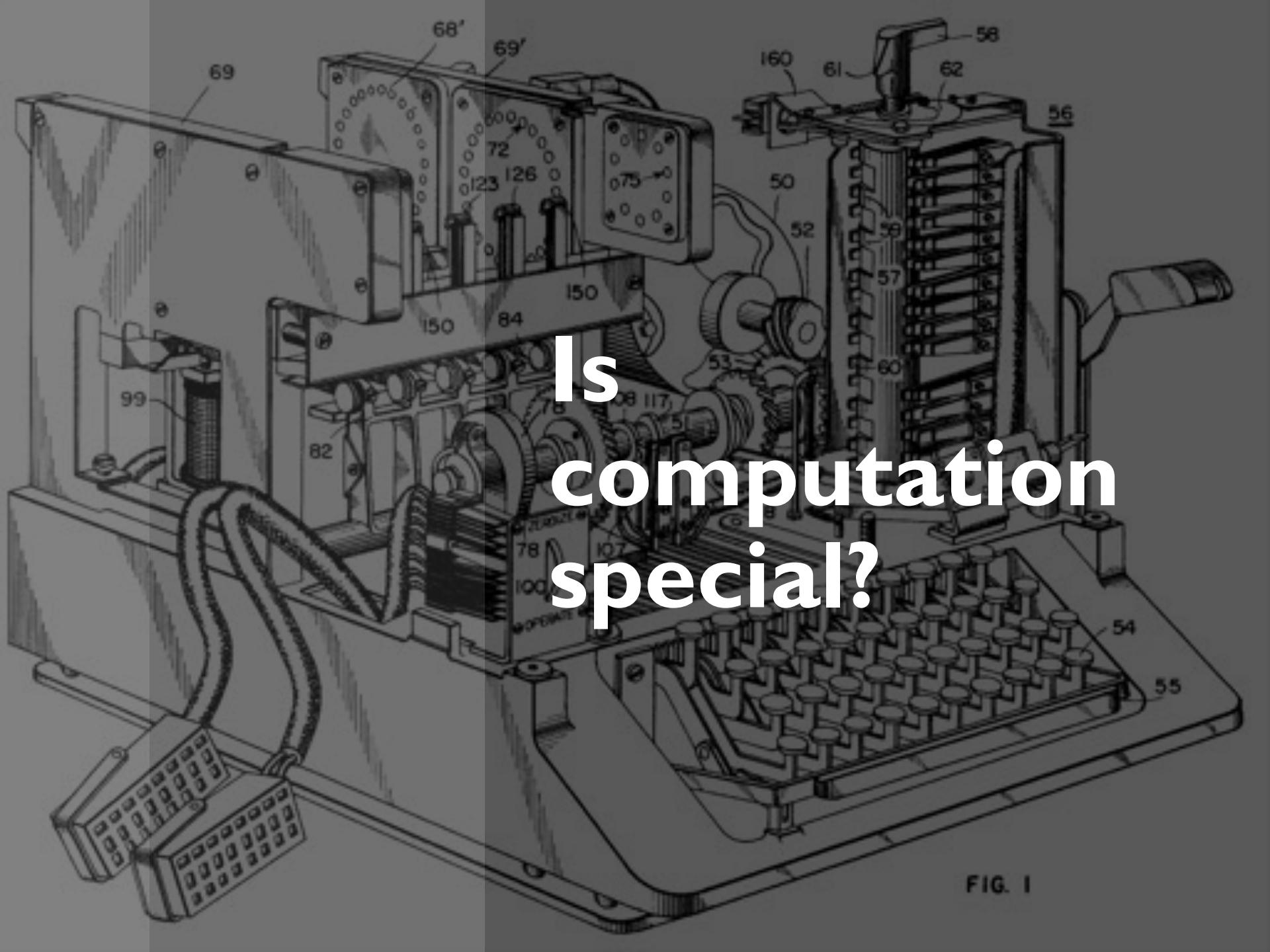
- Why do this?
  - Computational language is *precise*… we can generate empirically testable predictions (see: methodological behaviourism!)
  - Computational language is *flexible*... so we can postulate hidden mechanisms and structure to cognitive processes (goes beyond radical behaviourism)

Measuring cognition?

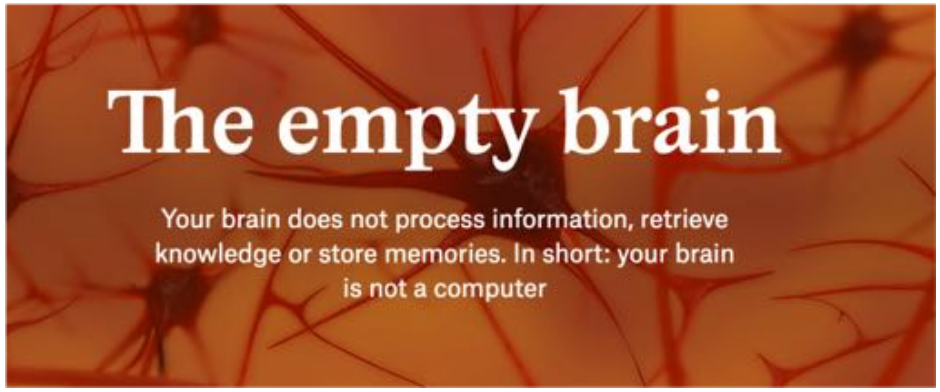
Common methods

- Accuracy of response
- Type of response
- Response time
- Neurological deficit
- Brain imaging
- Self-report

"hey…"



Is computation special?



https://aeon.co/essays/your-brain-does-not-process-information-and-it-is-not-a-computer

Robert Epstein

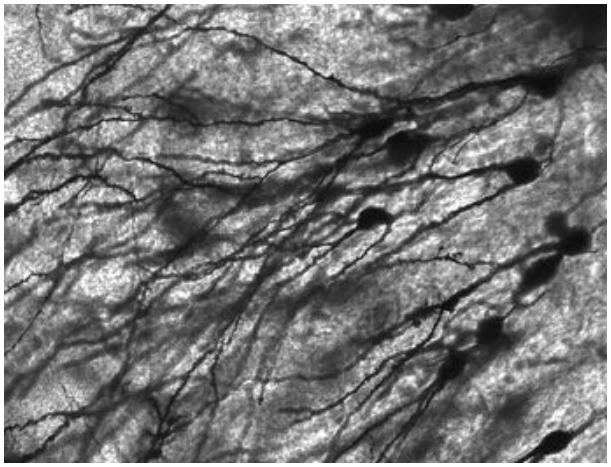
"Our shoddy thinking about the brain has deep historical roots, but the invention of computers in the 1940s got us especially confused. For more than half a century now, psychologists, linguists, neuroscientists and other experts on human behaviour have been asserting that the human brain works like a computer."

"Computers, quite literally, *process information* – numbers, letters, words, formulas, images. The information first has to be encoded into a format computers can use, which means patterns of ones and zeroes ('bits') organised into small chunks ('bytes'). On my computer, each byte contains 8 bits, and a certain pattern of those bits stands for the letter *d*, another for the letter *o,* and another for the letter *g*. Side by side, those three bytes form the word *dog*."

- Robert Epstein

- Danielle Navarro

Okay, let's take a closer look…



A superficial interpretation of the computational metaphor: these two machines are very similar to each other.

This claim is *obviously* wrong

“Intelligent Machinery”

Alan Turing

"Intelligent Machinery".

I propose to investigate the question as to whether it is possible for machinery to show intelligent behaviour. It is usually assumed without argument that it is not possible. Common catch phrases such as 'acting like a machine', 'purely mechanical behaviour' reveal this common attitude. It is not difficult to see why such an attitude should have arisen. Some of the reasons are

(a) An unwillingness to admit the possibility that mankind can have any rivals in intellectual power. This occurs as much amongst intellectual people as amongst others: they have more to lose. Those who admit the possibility all agree that its realization would be very disagreeable. The same situation arises in connection with the possibility of our being superseded by some other animal species. This is almost as disagreeable and its theoretical possibility is indisputable.

(b) A religious belief that any attempt to construct such machines is a sort of Promethean irreverence.

(c) The very limited character of the machinery which has been used until recent times (e.g. up to 1940). This encouraged the belief that machinery was necessarily limited to extremely straightforward, possibly even to repetitive, jobs. This attitude is very well expressed by Dorothy Sayers (The Mind of the Maker, p. 46) "... which imagines that God, having created his Universe, has now screwed the cap on His pen, put His feet on the mantelpiece and left the work to get on with itself." This, however, rather comes into St. Augustine's category of figures of speech or enigmatic sayings framed from things which do not exist at all. We simply do not know of any creation which goes on creating itself in variety when the creator has withdrawn from it. The idea is that God simply created a vast machine and has left it working until it runs down from lack of fuel. This is another of those obscure analogies, since we have no experience of machines that produce variety of their own accord; the nature of a machine is to do the same thing over and over again so long as it keeps going."

(d) Recently the theorem of Godel and related results (Godel 1, Church 1, Turing 1) have shown that if one tries to use machines for such purposes as determining the truth or falsity of mathematical theorems and one is not willing to tolerate an occasional wrong result, then any given machine will in some cases be unable to give an answer at all. On the other hand the human intelligence seems to be able to find methods of ever increasing power for dealing with such problems 'transcending' the methods available to machines.

(e) In so far as a machine can show intelligence this is to be regarded as nothing but a reflection of the intelligence of its creator.

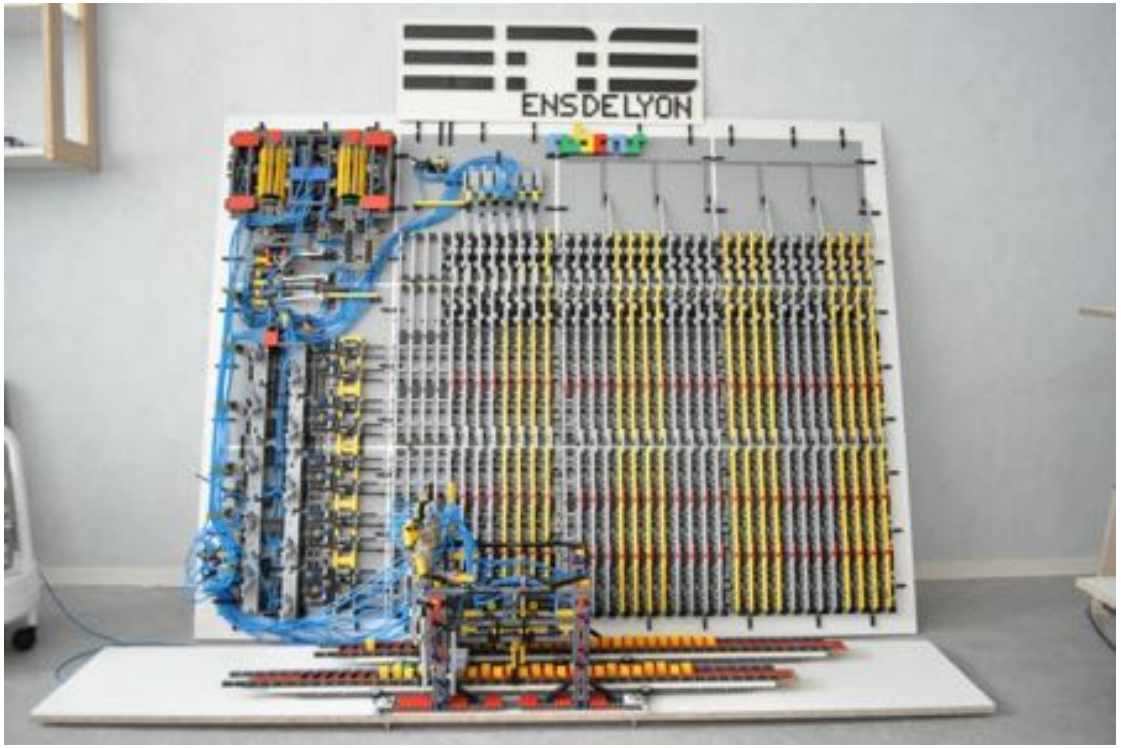
Turing machines

A Turing machine is a very simple (hypothetical) device that reads and writes symbols off a piece of tape…

… yet it is a **universal** computing machine. Anything that can be computed, can be computed with this machine*

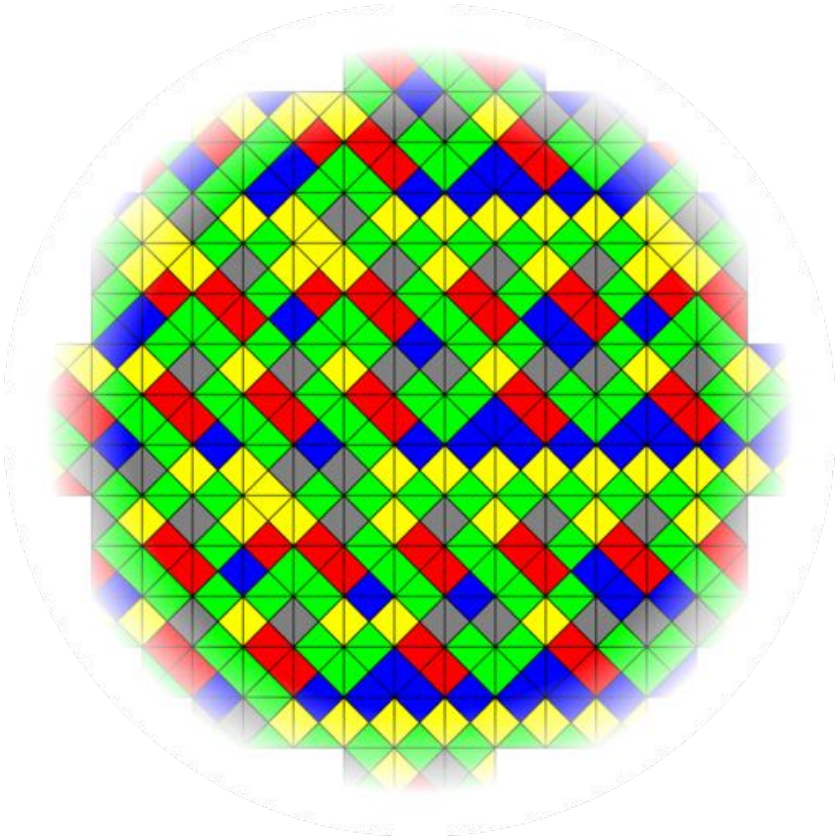
(*Sort of)

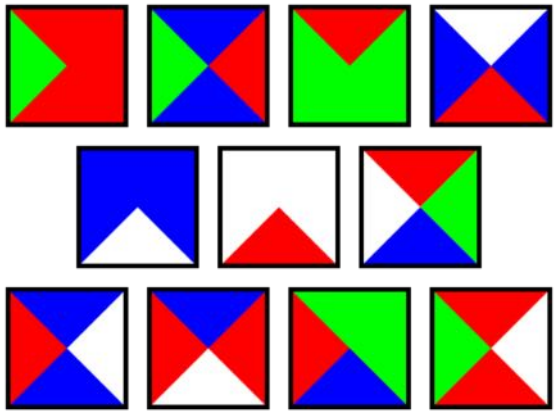
Digital computers are *much* fancier versions of Turing machines



But you can build a universal computing machine out of lego

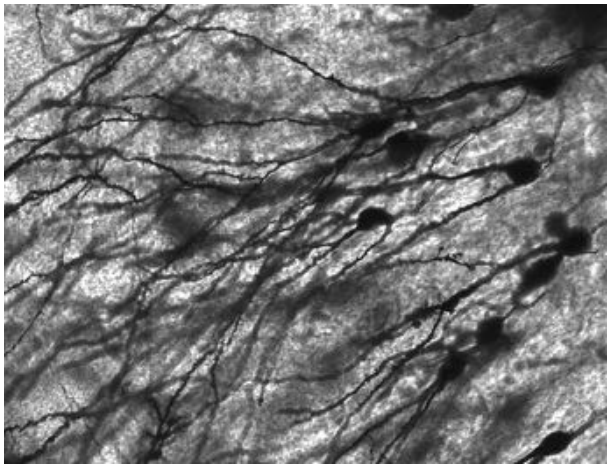
You can use "Wang tiles" on your bathroom floor …

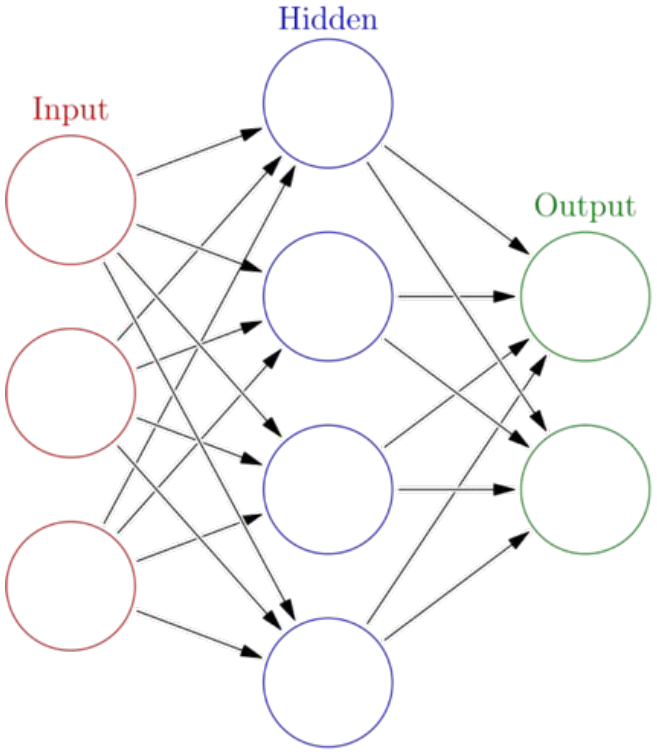




… and these tiles *also* describe a universal computing machine

"Neural networks" describe an information processing system that is inspired by the structure of the brain



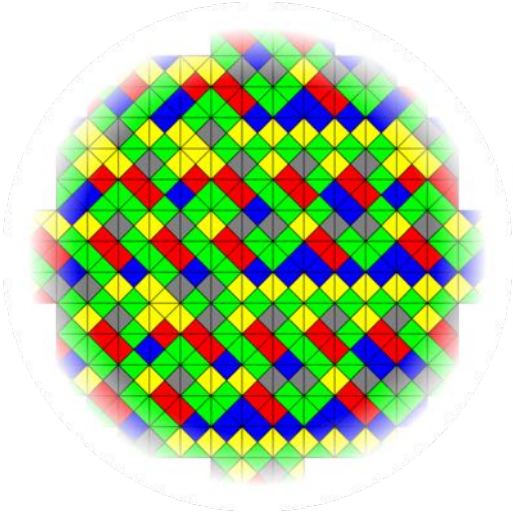


These are *also* universal computing machines

A "program" given to one universal Turing machine can be rewritten using the language of another universal Turing machine

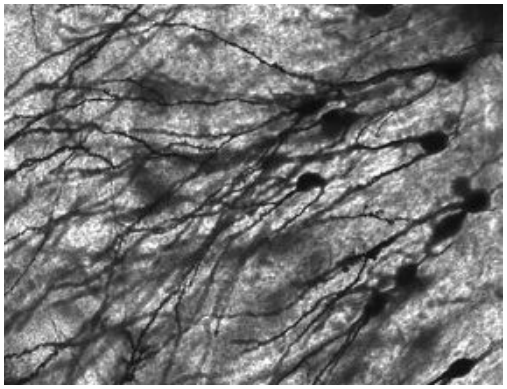
At a fundamental level what underpins the computational metaphor is the fact that these are all information processing machines ... they are *computers*

“The laptop fallacy”

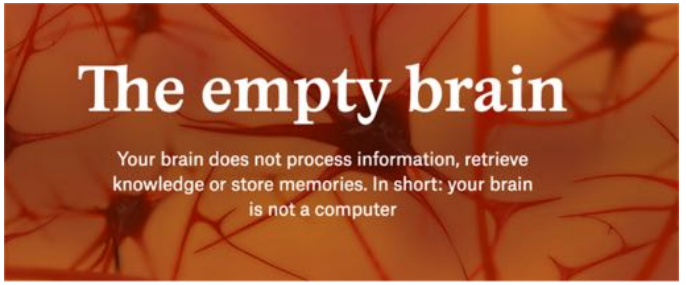


My bathroom floor doesn’t look very much like my laptop, therefore Wang tiles do not describe a computing machine?

“The laptop fallacy”



My brain doesn’t look very much like my laptop, therefore the human mind is not a computing machine?



Example: learning models used by behaviourists are computational models

Verbal description

"The more surprised an animal is, the more it will learn"

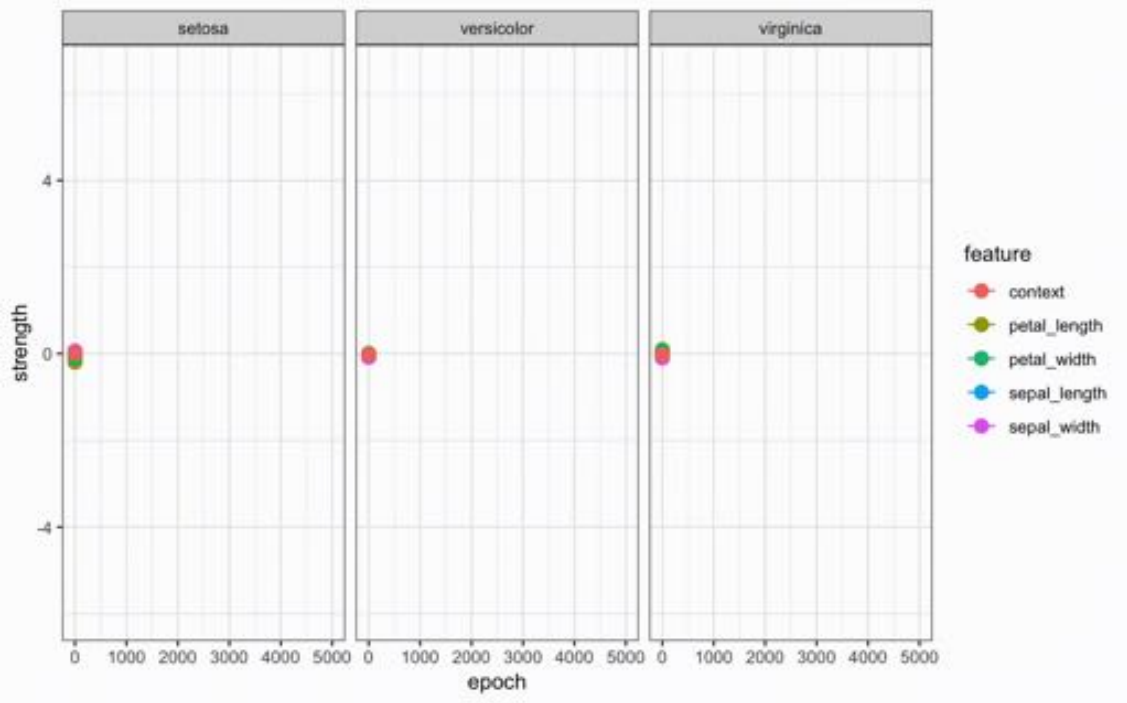
Mathematical description

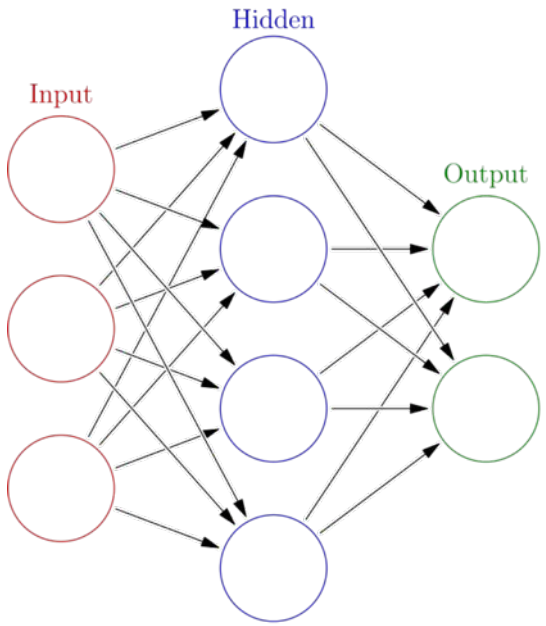
$$\Delta V = \alpha\beta(\lambda - \Sigma V)$$

Computational description

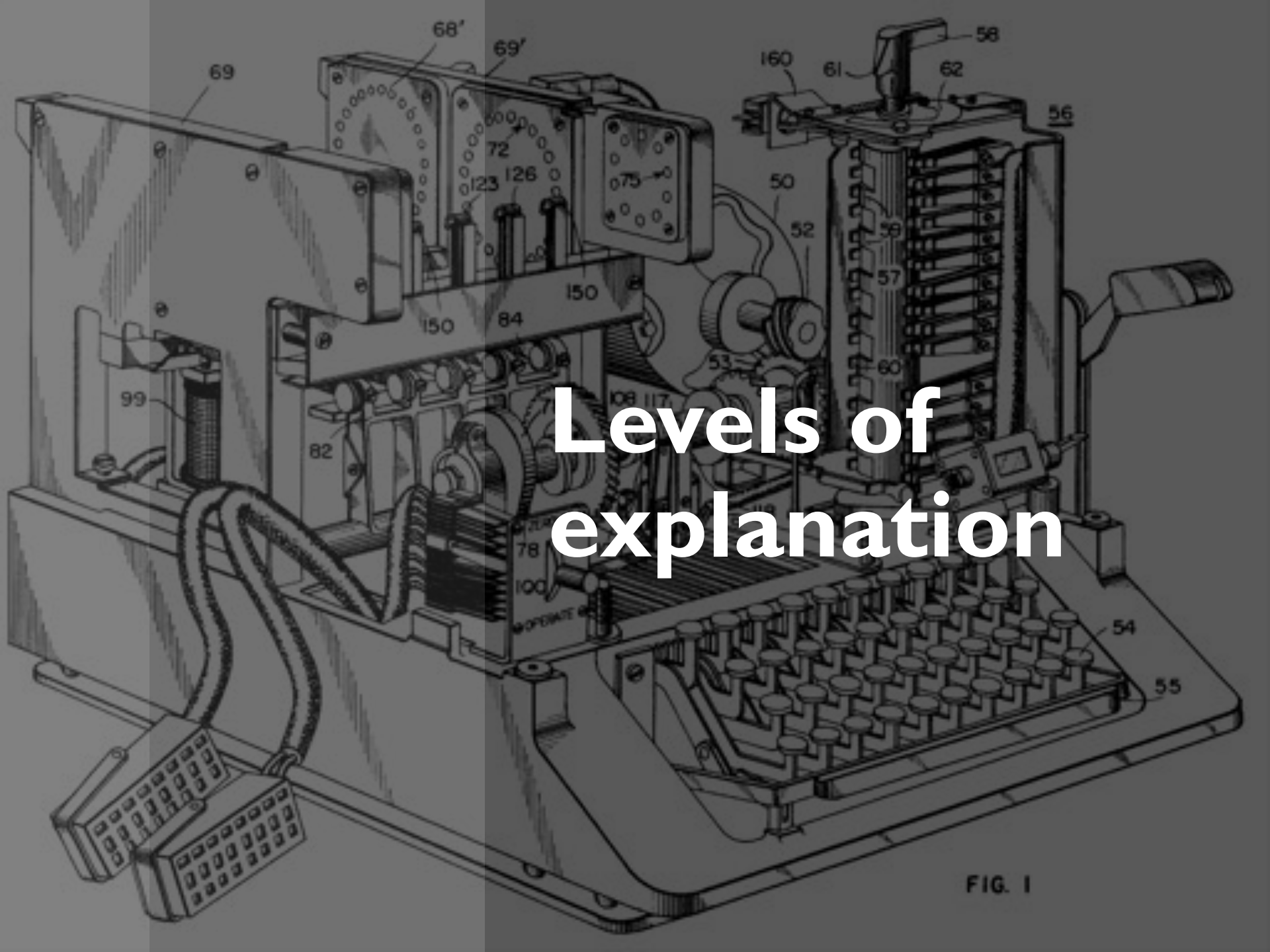
```
update <- function(V, a, b, l) {
    surprise <- l - sum(V)
    dV <- a * b * surprise
    return(V + dV)
}
```

http://compcogscisydney.org/psyr/programming.html

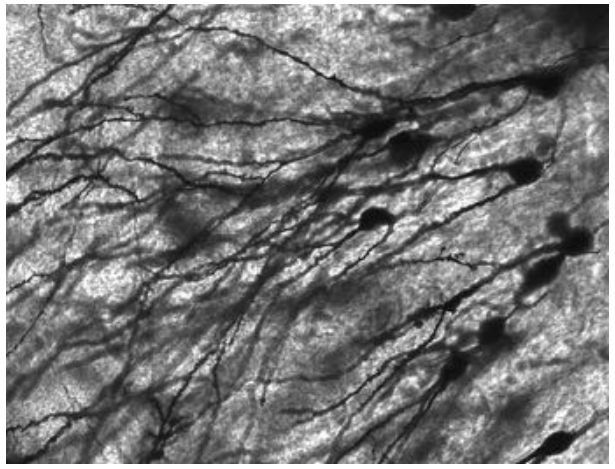




http://compcogscisydney.org/psyr/backprop.html



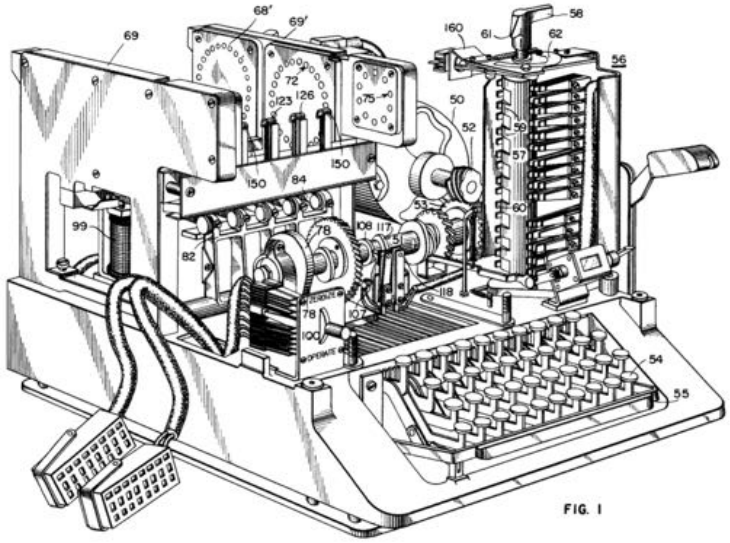
Levels of explanation

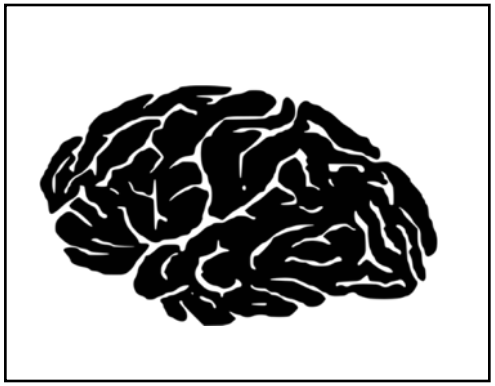


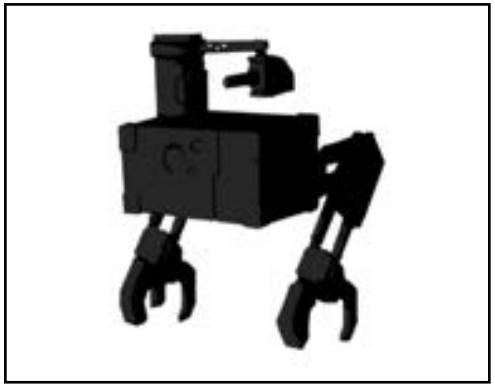
Cognition is performed by the brain, and our theories of cognition should informed by the biology of the brain

Cognition is a feature of intelligent agents, and our theories of cognition should be informed by understanding what intelligent agents do

Agreement?



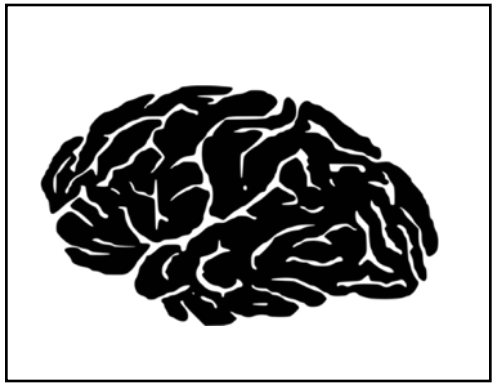




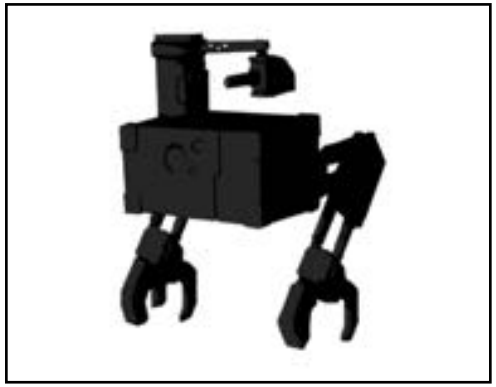
At an abstract level, cognition is a form of computation, and the brain does information processing

Disagreement?

What *mechanisms* does the brain use to perform computations?



What computational *problems* does the mind solve?



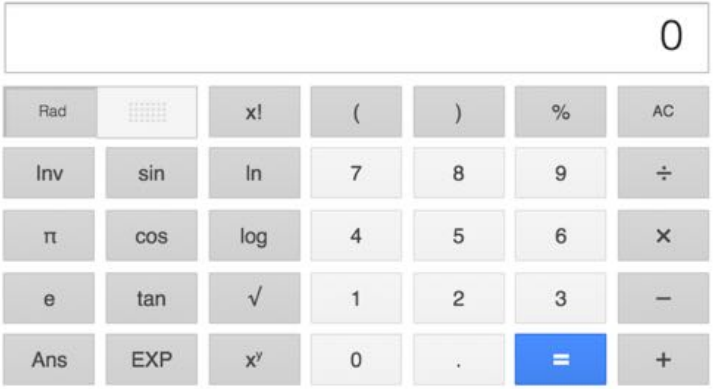
Describing the tension: Marr's "levels of analysis"

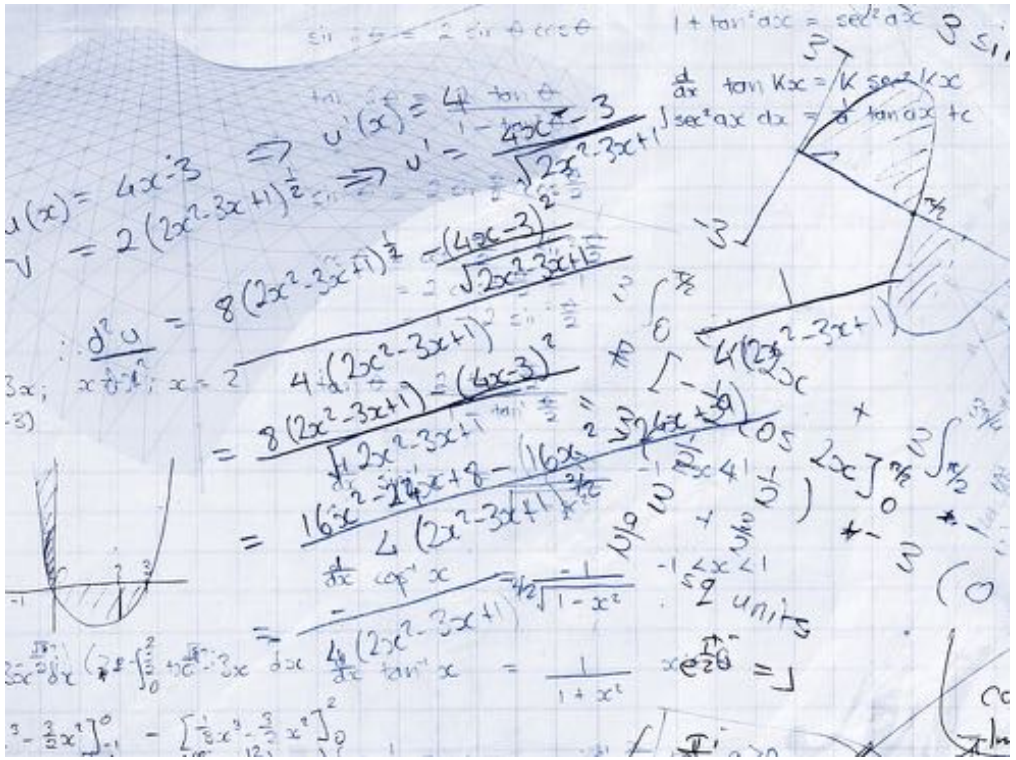
- *Abstract computation:* What problem does cognition solve?
- *Algorithm:* What processing steps does it follow to do so?
- *Implementation:* How is this instantiated as a physical entity?

(Marr 1980)

The computational level

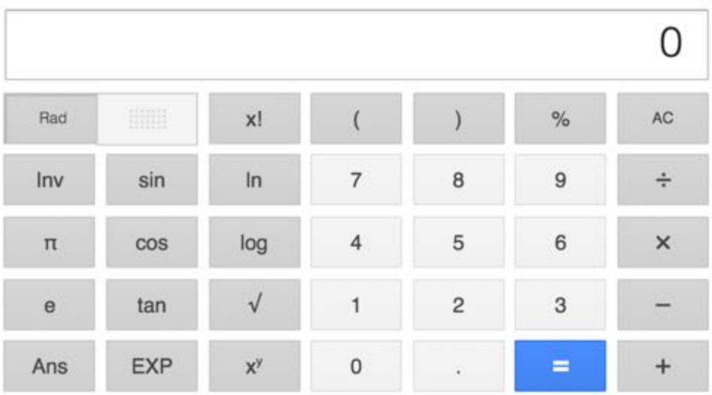
"The function of a calculator is to solve arithmetic problems"

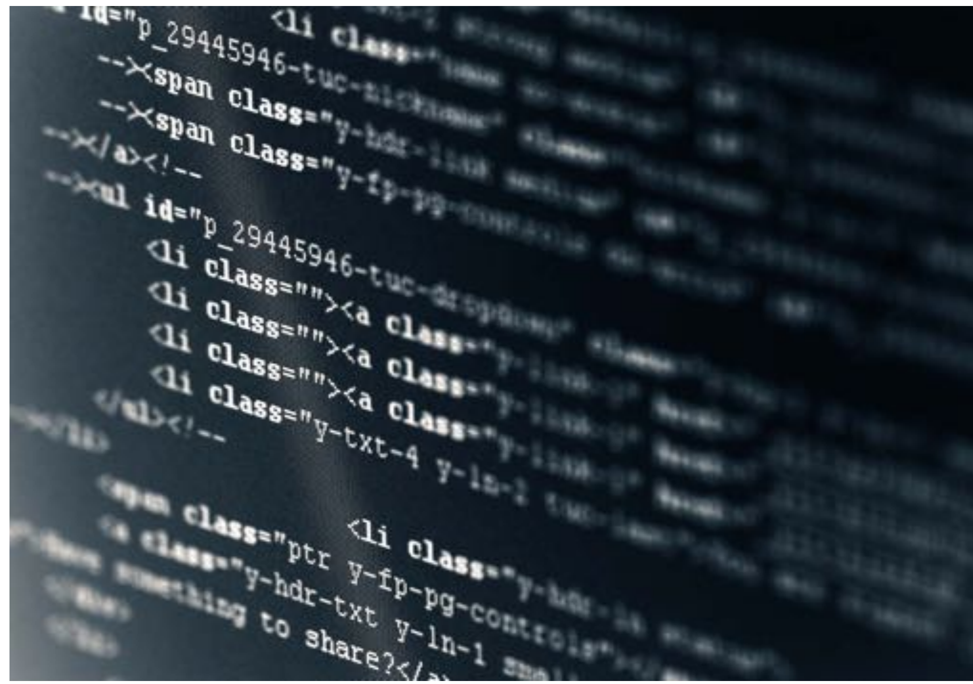




The algorithmic level

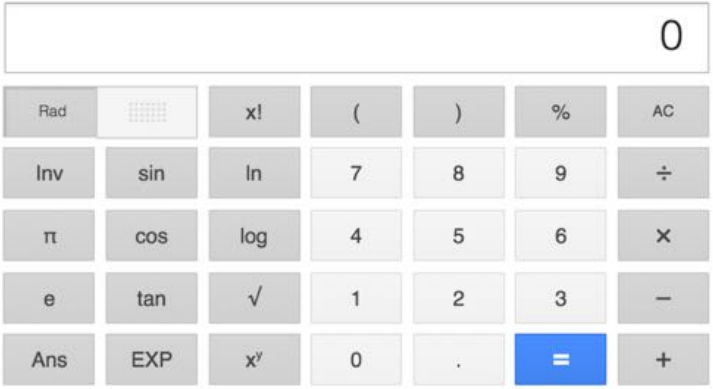
"Addition can be described using a computer program"

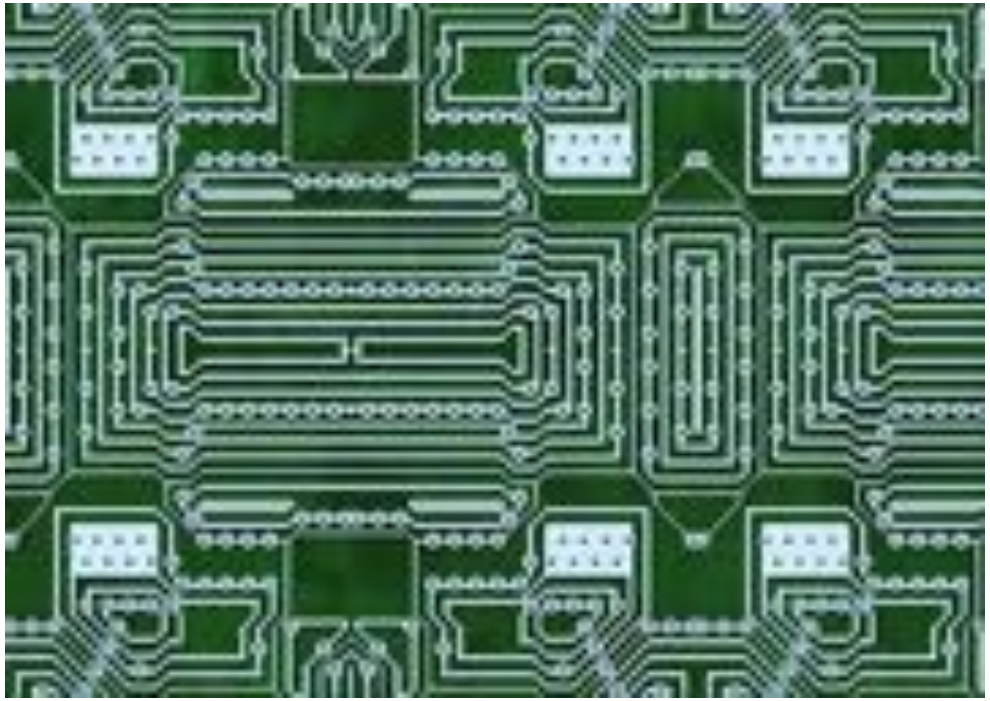




The implementation level

"A calculator uses circuitry to do calculations"





Computation

Machine learning

Statistics

Computer science

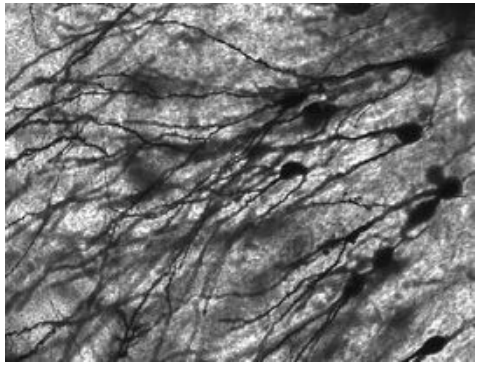
Algorithm

Psychology

Cognitive science

Neuroscience

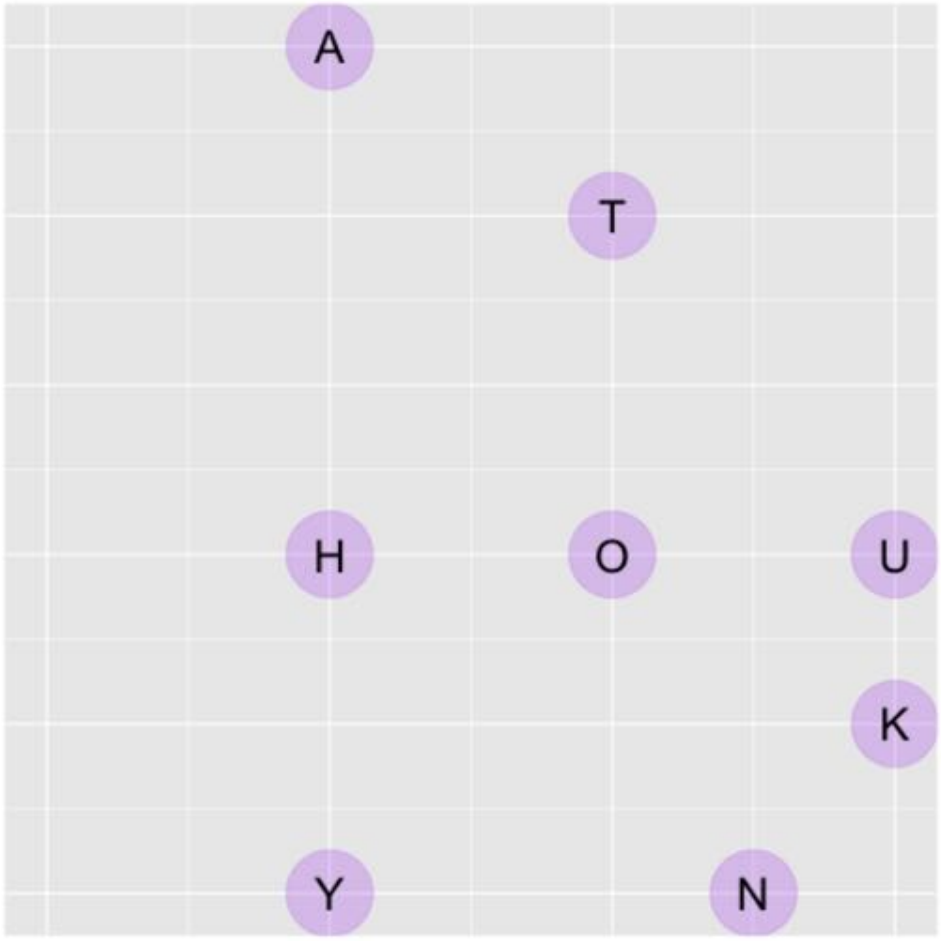
Implementation



Biology

What have we covered?

- The relationship between perception and cognition
- Behaviourism as a response to introspection
- Failures of the behaviourist view
- The computational metaphor
- Discussion of what "computation" means
- Discussion of Marr's levels of analysis


A
T
H
O
U
K
Y
N