

# Artificial Intelligence, Blockchain, e Criptovalute nello Sviluppo Software

## Lezione 5: Cognitive Models in Software Development – acquisition, retention, and use of information

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## Structure of the lecture

- The concept of cognition
- Early models
  - Attribution theory
  - The naïve scientist
  - Stereotypes
  - Heuristics
- Impulsive / Reflective model
- Implications for software production
- Everything we discuss here are **working hypotheses**: we have to remember that working hypotheses even if later proved to be wrong, helped the progress of science and technology, e.g., celestial spheres

Refer to [https://en.wikipedia.org/wiki/Celestial\\_spheres](https://en.wikipedia.org/wiki/Celestial_spheres)



# A working hypothesis

Schema huius præmissæ diuisionis Sphærarum .



Picture taken from [https://en.wikipedia.org/wiki/Celestial\\_spheres](https://en.wikipedia.org/wiki/Celestial_spheres)



# Cognition

- Our goal in this lecture is to present some paradigms discussing:
  - how information is acquired and stored
  - how such information is then used to make decisions
- In this context we review existing models of knowledge throughout their historical evolution

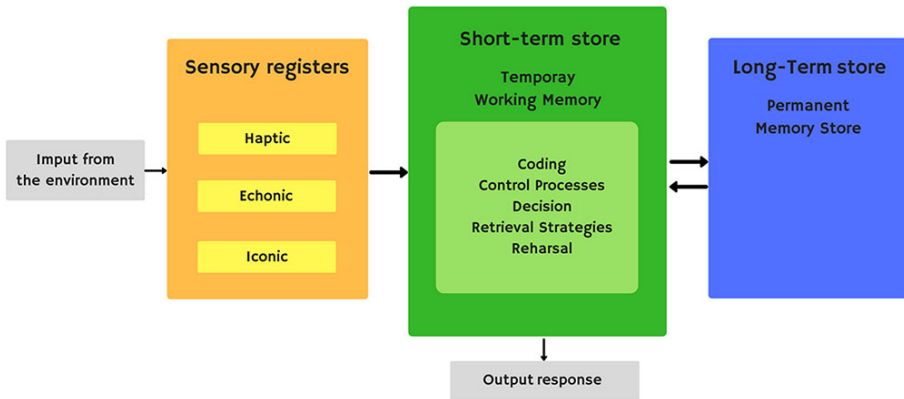


## Storing information

- There have been proposals to divide the storage of information in the human brain in two (or three) parts:
  - short term memory
  - long term memory
  - (working memory)
- we will now shortly review such concepts



# General Model



Picture taken from Camina Eduardo, Güell Francisco (2017). "The Neuroanatomical, Neurophysiological and Psychological Basis of Memory: Current Models and Their Origins." *Frontiers in Pharmacology* 8



## Short Term Memory

- Short term memory is a function of the brain finalized of storing information ready to be used for a short amount of time
- The time-span for storage of such information is of the order of 18 seconds
- Repetition helps in increasing the time the information is stored there
- Capacity is believed to be of  $7 \pm 2$  elements
- Some researchers include in it the working memory

Taken from [https://en.wikipedia.org/wiki/Short-term\\_memory](https://en.wikipedia.org/wiki/Short-term_memory)

Camina Eduardo, Güell Francisco (2017). "The Neuroanatomical, Neurophysiological and Psychological Basis of Memory: Current Models and Their Origins." *Frontiers in Pharmacology* 8



# Long Term Memory

- Long term memory is where the information is kept for a indefinite amount of time
- It is further divided into:
  - explicit (declarative) memory, then further divided into:
    - episodic memory
    - semantic memory
    - (autobiographic memory)
  - implicit (non declarative) memory, then further divided into:
    - procedural memory
    - emotional memory

Taken from [https://en.wikipedia.org/wiki/Long-term\\_memory](https://en.wikipedia.org/wiki/Long-term_memory)





# Typical Schema of Long Term Memory

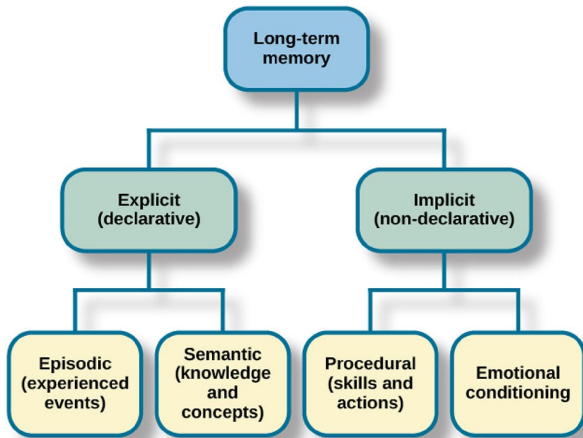
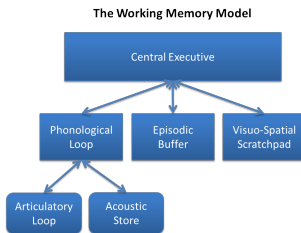


Image copied from <https://simplypsychology.org/long-term-memory.html> visited on 20230304, claimed author there: Saul Mcleod



# Working Memory (1/2)

- There are hypotheses that separated from the short term memory there is a memory retaining information for the specific purpose of making computations
- Such memory is called working memory
- There are proposals suggesting that it is multicomponent

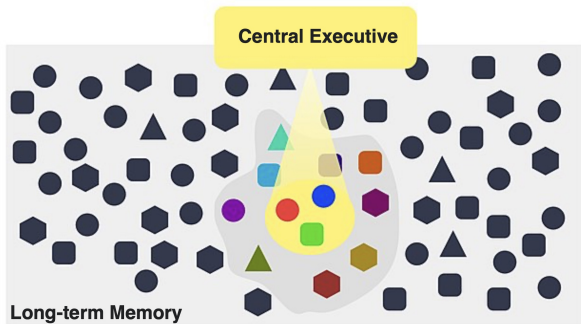


Taken from [https://en.wikipedia.org/wiki/Working\\_memory](https://en.wikipedia.org/wiki/Working_memory). The picture is credited there to come from Baddeley AD, Hitch G (1974). Bower GH (ed.). "Working Memory. Psychology of Learning and Motivation." Vol. 2. Academic Press. pp. 47–89.



## Working Memory (2/2)

- There are also hypotheses that the working memory is part of the long term memory
- Information is extracted from there with a kind of caching mechanism



Taken from [https://en.wikipedia.org/wiki/Working\\_memory](https://en.wikipedia.org/wiki/Working_memory). The picture is credited there to come from Ericsson KA, Kintsch W (April 1995). "Long-term working memory." Psychological Review. 102 (2): 211–245.



## Using knowledge

- We now review a series of models of how the knowledge is used to perform actions
- We focus on
  - attribution theory and the naïve scientist
  - the cognitive miser
  - the motivated tactician
  - the impulsive / reflective model
- considering a historical evolution



## Attribution theory (1/2)

- How do individuals attribute properties to entities they perceive?
- How do individuals attribute causes for what happens around them?
- Attribution bias/error
- Locus of causality
  - Internal attribution
    - attribution of the cause to self
  - External attribution
    - attribution of the cause to the environment

Taken from [https://en.wikipedia.org/wiki/Attribution\\_\(psychology\)](https://en.wikipedia.org/wiki/Attribution_(psychology))

Heider, F (1944). "Social perception and phenomenal causality." *Psychological Review*. 51 (6): 358–374.



## Attribution theory (2/2)

- Typical biases:
  - internal attribution:
    - positive own situations
    - negative situations of others
  - external attribution
    - negative own situations
    - positive situations of others
- Self-determination and feeling of autonomy

Taken from [https://en.wikipedia.org/wiki/Attribution\\_\(psychology\)](https://en.wikipedia.org/wiki/Attribution_(psychology))

Heider, F (1944). "Social perception and phenomenal causality." Psychological Review. 51(6):358–374.



# The Naïve Scientist

- Humans tries to provide a simple and rational explanation of all the details of the world around them
- They use the information available to them that they try to compose like in a puzzle
- When doing so they perform attributions

Taken from [https://en.wikipedia.org/wiki/Cognitive\\_miser](https://en.wikipedia.org/wiki/Cognitive_miser)

Duane T. Wegener and Richard E. Petty (1998) "The naive scientist revisited: Naive theories and social judgment" Social Cognition. 16(1):1



# Stereotypes

- Humans are not always able to handle complexity
- Understanding complexity requires effort
- A stereotype is a reconstruction of the reality where complex details are simplified
- Stereotypes are reinforced by looking at facts that from a simplistic perspective correspond to such stereotype
- Stereotypes simplify the thinking process

Taken from [https://en.wikipedia.org/wiki/Cognitive\\_miser](https://en.wikipedia.org/wiki/Cognitive_miser)





## Heuristics (1/4)

- Heuristics are another approach to cope with complexity
- We can define them as:
  - a fast answer to
  - a problem requiring for its full solution a **complex** procedure
  - answer that might be **occasionally wrong**
- People rely in heuristics to save time and effort

Taken from [https://en.wikipedia.org/wiki/Cognitive\\_miser](https://en.wikipedia.org/wiki/Cognitive_miser)  
Kahneman, Daniel and Tversky, Amos (1973) "On the psychology of prediction." Psychological Review.  
80 (4): 237–251



## Heuristics (2/4)

- There are multiple kinds of heuristics:
  - representativeness** heuristics:
    - people tend to generalize distributions ignoring the real rules of statistics.

*A cab was involved in a hit and run accident at night. Two cab companies, the Green and the Blue, operate in the city. 85% of the cabs in the city are Green and 15% are Blue. A witness identified the cab as Blue. The court tested the reliability of the witness under the same circumstances that existed on the night of the accident and concluded that the witness correctly identified each one of the two colours 80% of the time and failed 20% of the time. What is the probability that the cab involved in the accident was Blue rather than Green knowing that this witness identified it as Blue?*

(Tversky and Kahneman (1982) as quoted in wikipedia)

Taken from [https://en.wikipedia.org/wiki/Representativeness\\_heuristic](https://en.wikipedia.org/wiki/Representativeness_heuristic)

Gilovich, T., & Savitsky, K. (2002). Like goes with like: The role of representativeness in erroneous and pseudo-scientific beliefs. In T. Gilovich, D. Griffin, & D. Kahneman (Eds.), *Heuristics and biases: The psychology of intuitive judgment* (pp. 617–624). Cambridge University Press.

Tversky, A., & Kahneman, D. (1982). Evidential impact of base rates. In D. Kahneman, P. Slovic, & A. Tversky (Eds.), *Judgment under Uncertainty: Heuristics and Biases*. Cambridge University Press



## Heuristics (3/4)

- There are multiple kinds of heuristics:
  - **availability** heuristic:
    - “if something can be recalled, it must be important” (wikipedia)
    - people build their beliefs on facts that come to their mind faster – typically most recent facts
    - people make assumption on distributions on entities, events, etc. based on the frequencies of items of them coming to their minds

Taken from [https://en.wikipedia.org/wiki/Availability\\_heuristic](https://en.wikipedia.org/wiki/Availability_heuristic)

Kahneman, Daniel and Tversky, Amos (1973) “On the psychology of prediction.” *Psychological Review*.  
80 (4): 237–251



## Heuristics (4/4)

- There are multiple kinds of heuristics:
  - anchoring** or **adjustment** heuristic:
    - people based their opinion on a reference impression (the anchor) and then readjust it based on new information
    - often the reference impression is the first impression (but sometimes also the last)
    - can be effective in requirement negotiation

Taken from [https://en.wikipedia.org/wiki/Anchoring\\_\(cognitive\\_bias\)](https://en.wikipedia.org/wiki/Anchoring_(cognitive_bias))

Kahneman, Daniel and Tversky, Amos (1974) "Judgment under Uncertainty: Heuristics and Biases." Science. 185 (4157): 1124-1131

Yasseri, T., Reher, J. (2022) "Fooled by facts: quantifying anchoring bias through a large-scale experiment." Journal of Computational Social Science. 5: 1001-1021



# The Cognitive Miser

- The theory of cognitive miser clusters observations and theories about how people reason on facts
- It includes the concepts of stereotypes and heuristics
- It is centered on the idea that people tend to be miser (scrooge) in using their cognitive resources when analysing facts and building knowledge
- The essence is that people make decisions trying to minimize their effort

Taken from [https://en.wikipedia.org/wiki/Cognitive\\_miser](https://en.wikipedia.org/wiki/Cognitive_miser)



# The Motivated Tactician and the Meaning Seeker

- We can perceive the naïve scientist and the cognitive miser as two extremes of a continuous of positions on how the mind works
- It has been also proposed that there are also people who may select which option to follow based on the context in which they are
  - this gives raise to the concept of **motivated tactician**
- there is also the proposal rooted on the concept of Kant categories that are used to represent knowledge as a kind of point in a space of multiple dimensions (the categories)
  - the concept of the **meaning seeker** consider people in the quest for a comprehensive understanding of the work

Taken from [https://en.wikipedia.org/wiki/Cognitive\\_miser](https://en.wikipedia.org/wiki/Cognitive_miser)



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## The Dual Process Theory (1/2)

- Sometimes information is processed and knowledge is created through two different and, sometimes, concurrent processes:
  - a **conscious**, explicit, and rational (to the extent discussed before) process
  - an **unconscious**, implicit / automatic process
    - think for instance at when **we drive the car in “automatic” mode** and then we get a high level of attention for something unexpected happening
- There has been multiple models presenting this duality

Taken from [https://en.wikipedia.org/wiki/Dual\\_process\\_theory](https://en.wikipedia.org/wiki/Dual_process_theory)





## The Dual Process Theory (2/2)

- As an example, Evans suggested that there are:
  - an **heuristic** process, where the relevant information is selected
  - an **analytical** process, where the information is processed and deductions are made
- There are also theories claiming the opposite:
  - the **dynamic graded continuum** claims that there are a multitude of different possible representations generated by the mind that triggers different reasoning processes depending on situations without assuming a dual process
- particularly interesting is the model of Strack and Deutsch on the **reflective and impulsive dual mode of operations**

Taken from [https://en.wikipedia.org/wiki/Dual\\_process\\_theory](https://en.wikipedia.org/wiki/Dual_process_theory)

Evans, Jonathan (1984). "Heuristic and analytic processes in reasoning." *British Journal of Psychology*. 75(4):451-468



## The Reflective / Impulsive Model (1/7)

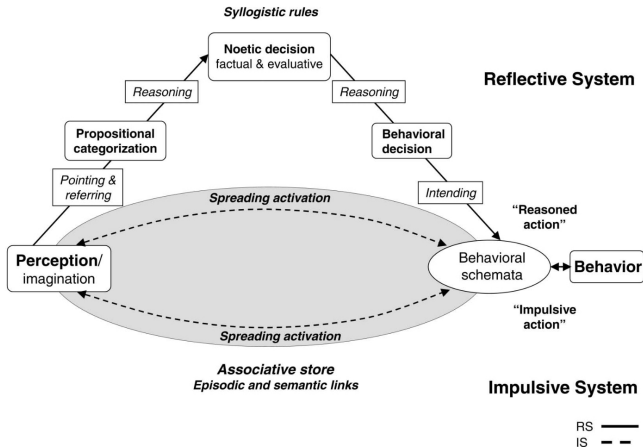
- It explains the reasoning process as the result of two interacting processes:
  - an implicit **impulsive** process that reacts fast based on a kind of associative memory
  - an explicit **reflective** process that generates knowledge following a reasoning process
- the two systems work concurrently, sometimes with coherent results, sometimes in opposition
- this approach provides an explanation of several phenomena involving the human mind, including, for instance, how software inspections often work

Taken from Strack F, Deutsch R. "Reflective and impulsive determinants of social behavior." *Personality and Social Psychology Review*. 2004;8(3):220-47.



# The Reflective / Impulsive Model (2/7)

## • The overall model

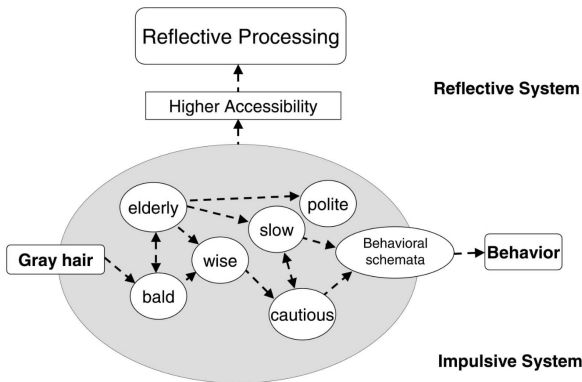


Picture copied from page 222 of Strack F, Deutsch R. "Reflective and impulsive determinants of social behavior." *Personality and Social Psychology Review*. 2004;8(3):220-47.



## The Reflective / Impulsive Model (3/7)

- Example of synergistic work – how the concept of elderly person is generated by the impulsive system

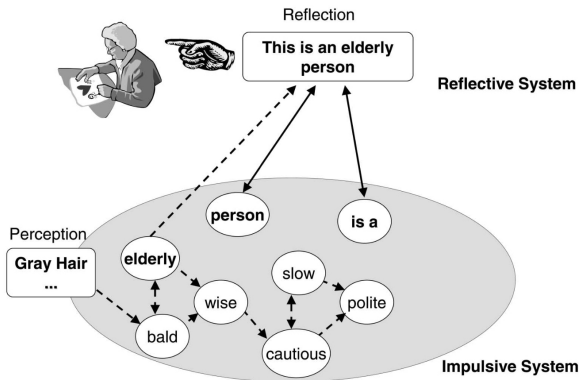


Picture copied from page 224 of Strack F, Deutsch R. "Reflective and impulsive determinants of social behavior." *Personality and Social Psychology Review*. 2004;8(3):220-47.



## The Reflective / Impulsive Model (4/7)

- Example of synergistic work – how the concept of elderly person is generated by the reflective system

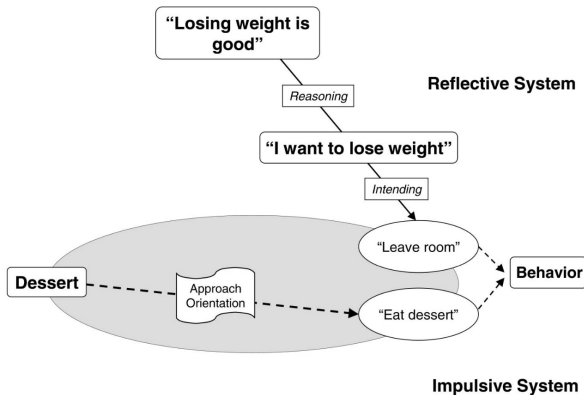


Picture copied from page 225 of Strack F, Deutsch R. "Reflective and impulsive determinants of social behavior." *Personality and Social Psychology Review*. 2004;8(3):220-47.



## The Reflective / Impulsive Model (5/7)

- Example of competing work – eating the dessert or staying on diet?

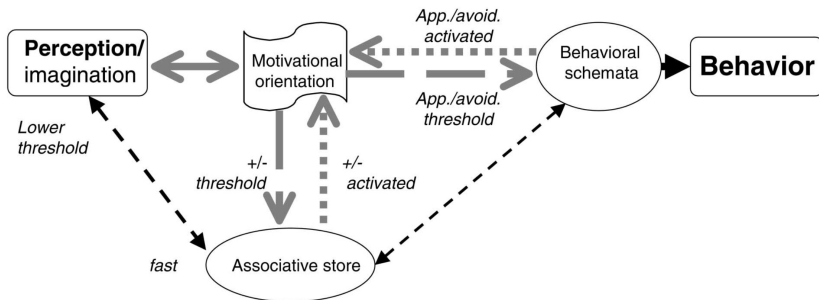


Picture copied from page 231 of Strack F, Deutsch R. "Reflective and impulsive determinants of social behavior." *Personality and Social Psychology Review*. 2004;8(3):220-47.



# The Reflective / Impulsive Model (6/7)

- How motivational orientation could be explained

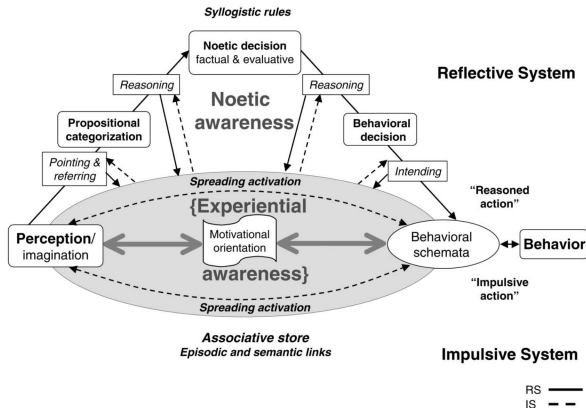


Picture copied from page 232 of Strack F, Deutsch R. "Reflective and impulsive determinants of social behavior." *Personality and Social Psychology Review*. 2004;8(3):220-47.



# The Reflective / Impulsive Model (7/7)

## Overall view of the model



Picture copied from page 239 of Strack F, Deutsch R. "Reflective and impulsive determinants of social behavior." *Personality and Social Psychology Review*. 2004;8(3):220-47.