Human Factors and Artificial Intelligence

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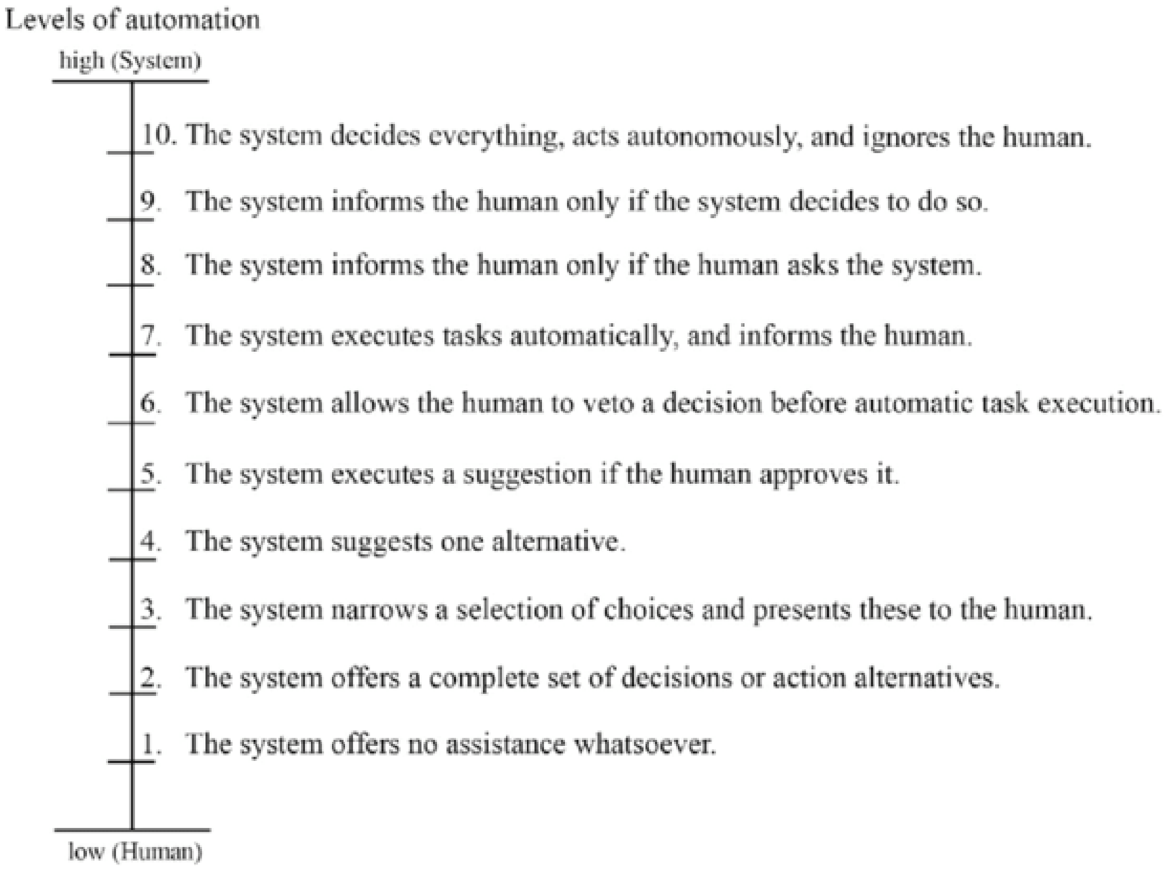
Introduction

- During the 20th century, work has evolved from being very « do-dependant » to « think-dependant » (Hollnagel, 1995) .
- Tasks have Evolved from sensori-motor (manual tasks, procedure-based and repetitive) to cognitive (diagnostic, planification and problem solving).
- After learning, sensori-motor tasks does not need much attention or cognitive effort for humans
- Cognitive tasks need to be capable of anticipation, being aware of the current situation, and to think more than « working with hands ».
- Nowadays, it means supervising or monitoring systems that are more and more automated and even maybe autonomous.

Level of Automation (taxonomy)



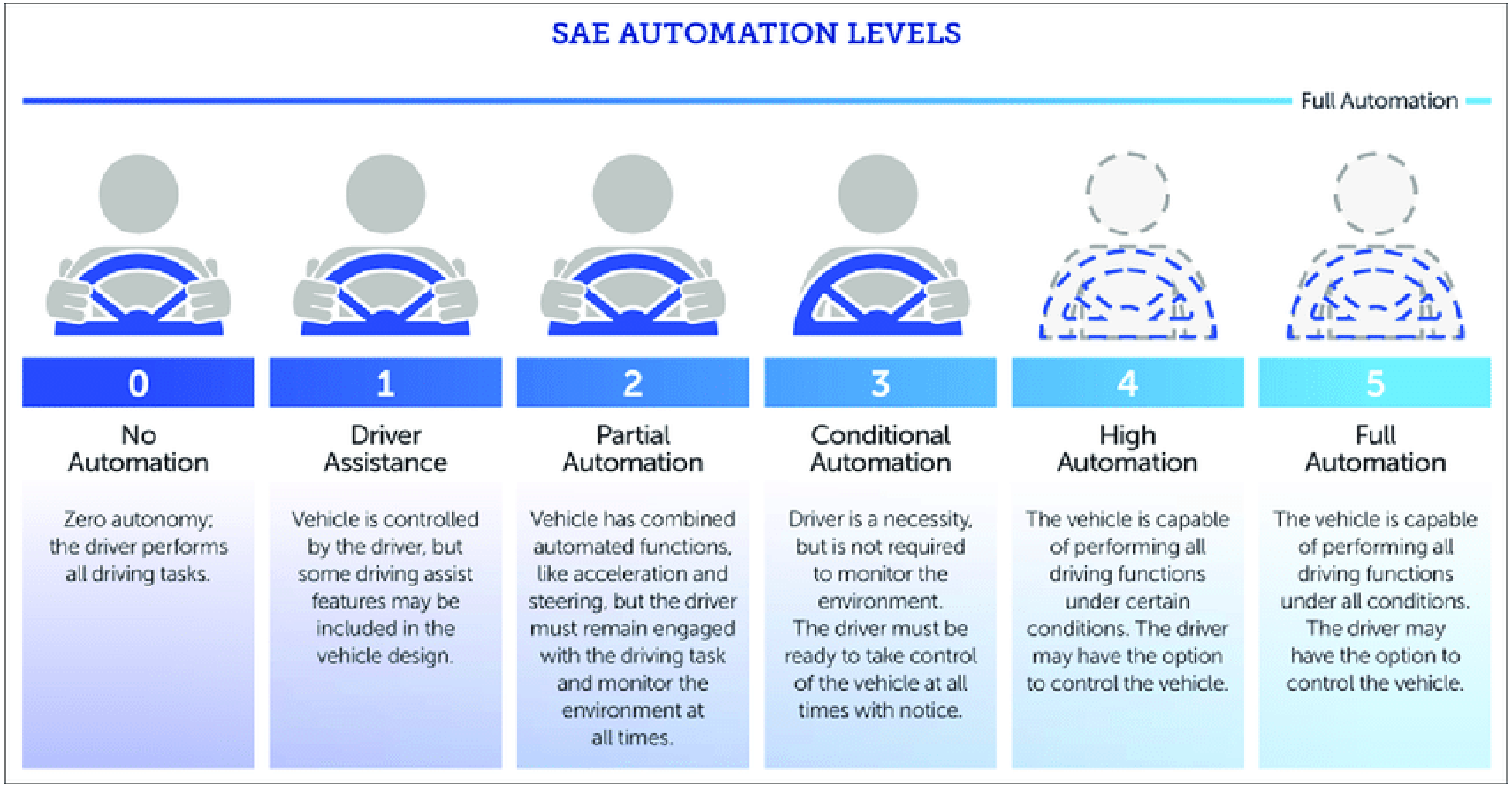
Sheridan and Verplanck (1978)

10 levels taxonomy of LOA

10. **Full Automation** (FA)
9. **Supervisory Control** (SC)
8. **Automated Decision Making** (ADM)
7. **Rigid System** (RS)
6. **Blended Decision Making** (BDM)
5. **Decision support** (DS)
4. **Shared Control** (SHC)
3. **Batch Processing** (BP)
2. **Action Support** (AS)
1. **Manual Control** (MC)

Kaber and Endsley (1997)

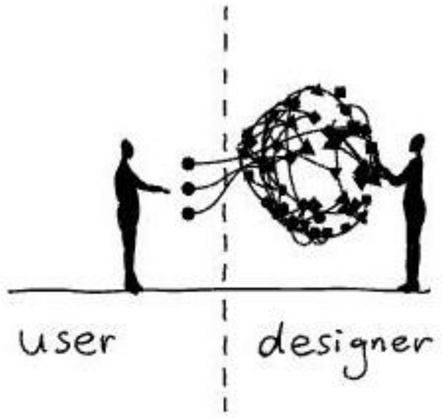
Level of Automation (Example in Industry)



Source: SAE Standard 2016 and NHTSA 2017

Introduction to Human Factors

- Therefore, taking into account the cognitive abilities of humans is becoming an important necessity during the design process of complex systems.
  - Complexity from the user point of view :



« Taking into account the human factors » during human-machine system design lead to two types of research (Dejours, 1995) :

- The origins and means of control for **human failure** in work situation
- The models and the means for recruiting, developping and **managing human and machine ressources** for work situation

Introduction

Some examples of Human Factors (sub-disciplines) :

- **Organizational factors** = Work organisation, policies, roles and responsabilities
- **Environmental factors** = Noise, Heating, Lighting, Vent wind -> LOL
- **Health and Safety** = Stress, Headaches, musculo-squelettical and biomechanical disorders
- **Cognitive factors of the user** = motivation, satisfaction, engagement, pleasure, personality, qualification and experience level
- **Comfort factors** = Seated position, equipement and Workplace design
- **Ergonomic factors of the user interface** = Input tools (for commands), output display, color usage, icons, graphics, natural language, 3D vision, operational documentation, multimedia settings
- **Task factors** = easiness, complexity, novelty, task allocation, repetitive aspects, monitoring, sub-tasks components, skill
- **Constraints** = costs, time scales, budgets, ressources, equipment, buildings
- **System functionalities** = hardware, software, application
- **Productivity factors** = increasing output, improving quality, reduce costs, decrease errors, reduce needs, lower production time, improving creative and innovative ideas for new products
- **Cooperation factors** = team work

Introduction

- The Human – Interface problem
- Not « How to design » but « what » to design and « why ?
- Can a system be qualified « intelligent » because it :
  - is supercomplex?
  - has the best performance?
  - does not fail?
  - is better than current state of the art?

- Cognitive System Engeneering (Hollnagel & Woods, 1983)
- User-centered Design (Norman & Draper, 1986)

put your device in use of target users as erly as possible
to catch stupid errors

- Function and Task allocation – Roles and Responsibilities

The original HABA-MABA List

What Human Are Better At ? What Machines are Better At ?

Humans appear to surpass present-day machines in respect to the following:	Present-day machines appear to surpass humans in respect to the following:
1. Ability to detect a small amount of visual or acoustic energy	7. Ability to respond quickly to control signals and to apply great force smoothly and precisely
2. Ability to perceive patterns of light or sound	8. Ability to perform repetitive, routine tasks
3. Ability to improvise and use flexible procedures	9. Ability to store information briefly and then to erase it completely
4. Ability to store very large amounts of information for long periods and to recall relevant facts at the appropriate time	10. Ability to reason deductively, including computational ability
5. Ability to reason inductively	11. Ability to handle highly complex operations, i.e. to do many different things at once
6. Ability to exercise judgment	

Source : Fitts 1951

Main problematic in Ergonomics and Human Factors : What should we automate and why ?

- What machines are/aren’t good at ?
- What humans are/aren’t good at ?

- Which tasks should be allocated to humans ?
- Which tasks should be allocated to machines ?

Brainstorm : 3 groups

A few proposals to think about :

GROUP 1

- Judgement
- Computation
- Detection

GROUP 2

- Speed & Power
- Perception
- Improvisation
- Simultaneous Operations

GROUP 3

- Long Term Memory
- Short Term Memory
- Replication
- Induction

Tasks and functions allocation between man and machines

- Simple Poll

3 categories :
Machines are better at

Humans are better at

It depends ?

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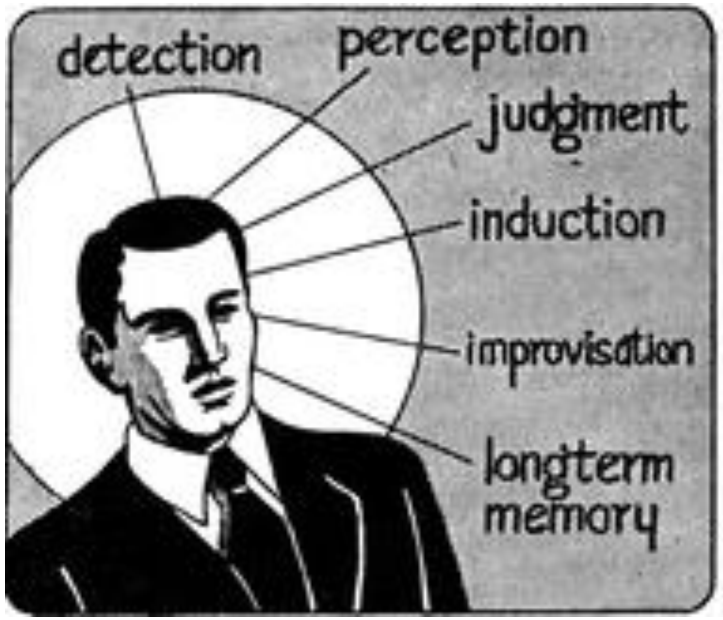
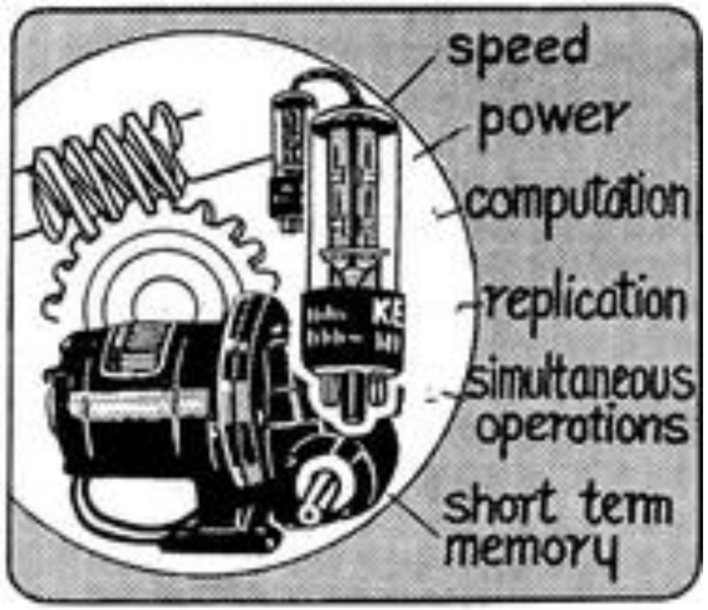


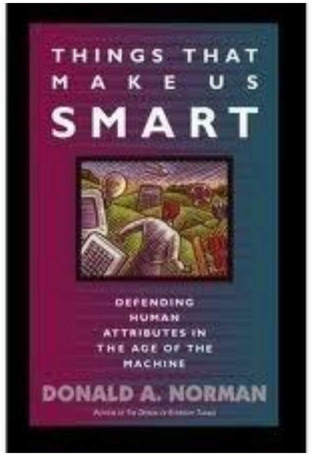


Some cognitive psychology aspects

- What Humans are good at ?
- What humans are very bad at ? And why ?

What Humans are good at ? (examples)

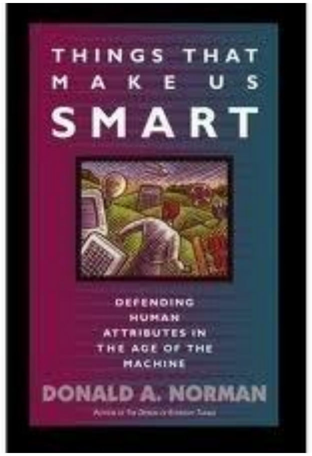
- Linking between objects and concepts
- Learning through analogy
- Rapidly recall an information from memory
- Comparing elements 1-by-1
- Recognizing patterns and similarities
- Being creative and imaginative
- Exercise judgment
- Prioritize elements from criteria



Norman 1993 « Things that makes us smart in the age of the machine »

What Humans are good at ?

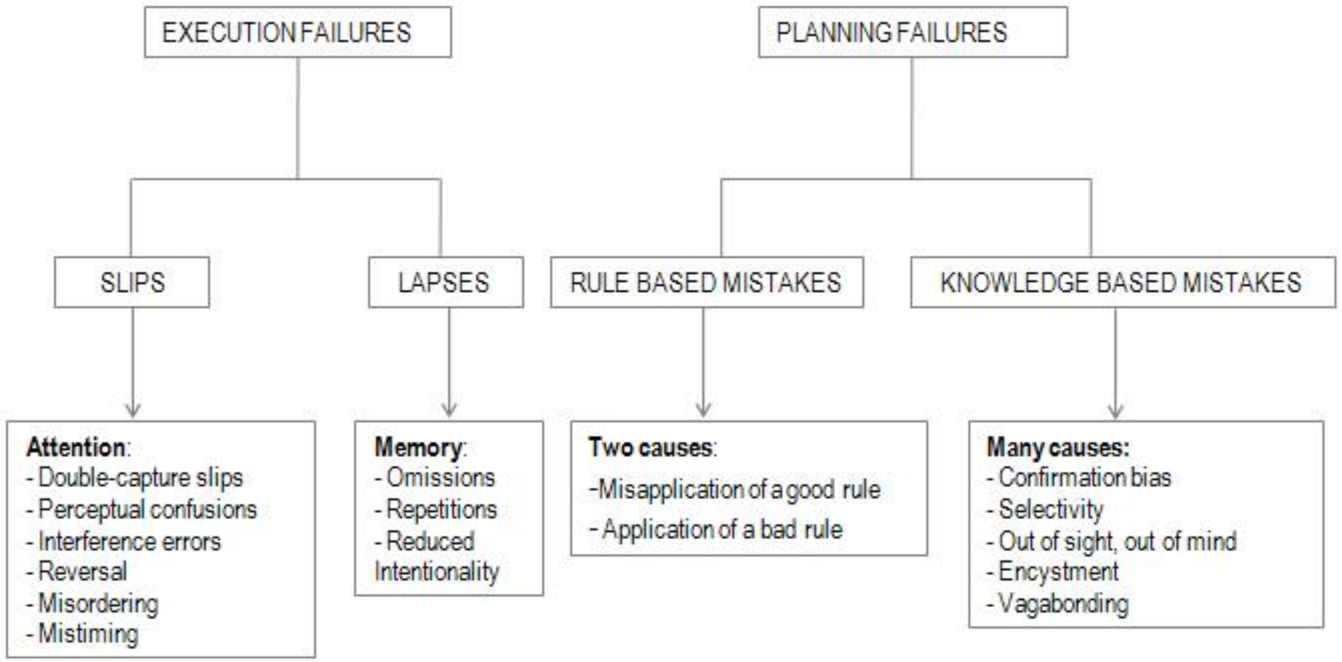
- Filtering irrelevant information
- Scheduling and reallocating activities to meet contextual constraints
- Anticipating events
- Making generalisations and inferences
- Learning from past experience
- Collaborating
- Etc..



Norman 1993 « Things that makes us smart in the age of the machine »

What are the typical Humans weakness?

- Make a lot of mistakes and errors !!
    - Slips, Lapses, Mistakes – Rules-based or Knowledge-based



What are the typical Humans weakness?

- Lack of reliability (mind wandering, lack of detection or false alarms)
- The human short-term memory have a very limited capacity (around 7±2 items)
- Human have difficulty with details (need important attention and precision)
- Human are not systematic (cannot repeat themselves)
- Human are bad at optimizing (stop looking for a solution when one is satisfying = « satisficing »)
- Cannot extrapolate or anticipate very long time in advance
- Humans posses a rough, incomplete, more or less accurate and mismatched mental model of the artefact that they use.

Some Statistics about Humans…

- Life Expectancy (More than 80+)
- Around 42% of population more than 45+ (source : Canada)
- Left Handed People (between 11% and 13% of World population)
- Colorblind (8.5% of men and 0.4% of women)
- 10 to 20% physical or mental disabilities (Newel & Gregor 1997)
  - Auditive disability 1/10thn Deafness : 1/125
  - Visual deficiency 1/100, 1/475 is legally considered Blind, 1/2000 totally blind
  - Wheelchair 1/250
  - 6 millions people with mental disabilities in the US and 2 millions living in mental instutitions

The Study of Mental process

- Important changes in psychology
- From behaviorism to cognitivism (late 50s – 60s)
- « Cognitive revolution »:
  - The vast complexity of human behavior cannot be summarized in a mere sum of stimuli, responses and reinforcing factors
  - We need a more complex model to explain memory, langage, mental representations, and knowledge acquisition during infant development
  - « Information processing » from computer sciences insist on two aspects:
    - A mental process can be compared to a computer process
    - A mental process can be interpreted as a progress of information within a system through different steps from stimuli to response
    - (Mandler 1985, Eyesenk 93, Massaro & Cowan 93)

  - Today theory more in favor of parallel processing of information on many distributed networks organized around a centralized counsicous workspace

Typical mental process (cognitive operations)

- Perception
- Attention
- Memory
  - Short term memory
  - Long term memory
  - Working memory
- Mental imagery
- Language / Semantics / Production
- Problem solving / Creativity
- Logics, reasoning, decision making

Aspects of human cognitive process

- Rather than passive, cognitive process are active
  - Individuals are actively seeking for information, memory is not passive storage of information but a dynamic and active process, etc.
- Cognitive process are very precise and efficients
  - Number of informations, complexity, etc…
- Cognitive process better process positive information than negative
- Cognitive process are interdependant, they never operate in isolation
- Cognitive process are both ascending (Bottom-up) and descending (Top-down)

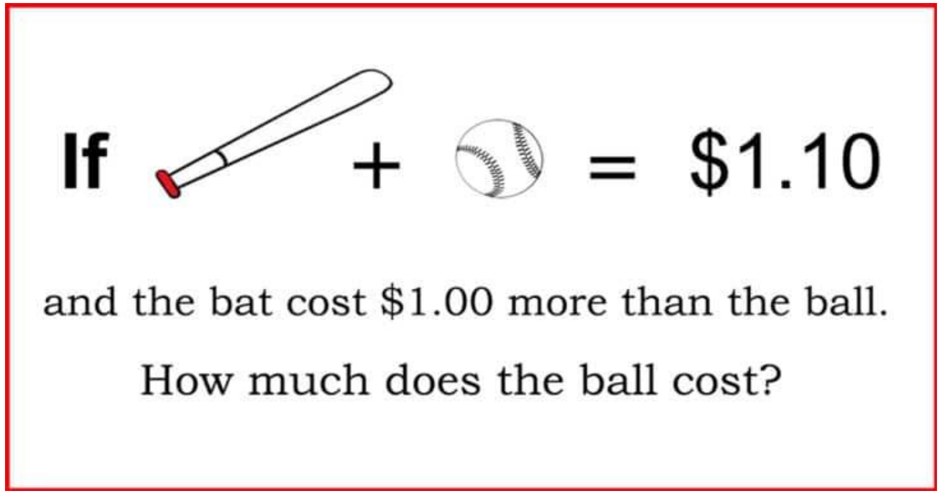
Different way of thinking

Stroop Effect

YELLOW

BLUE

Different way of thinking



Kahneman (2011) « Thinking Fast and Slow »

Different way of thinking

- System 1: « Fast instinctive and emotional »
- System 2: « Slower, more deliberative and more logical »

System 1	System 2
Unconscious reasoning	Conscious reasoning
Mostly involuntary	Mostly voluntary
Mostly linked to emotions ("gut feeling")	Mostly detached from emotions
Implicit	Explicit
Automatic	Controlled
Low Effort	High Effort
Large Capacity	Small Capacity
Rapid	Slow
Default process (suppressed by System 2, intense concentration)	Inhibitory (suppressed by clearing mind, meditation)
Association (A↔B)	Implication (A→B)[1]
Contextualized	Abstract[1]
Domain-specific	Domain-general
More subjective, Value-based	More objective, Fact/Rule-based
Evolutionarily old	Evolutionarily recent
Nonverbal	Linked to language
Includes recognition, perception, orientation.	Includes rule following, comparisons, weighing of options.
Modular Cognition	Fluid Intelligence

Kahneman (2011) « Thinking Fast and Slow »

Independent of working memory.	Limited by working memory capacity.
Intuitive, Creative	Logical, Rational
Metaphorical, Figurative	Literal, Exact
More qualitative	More quantitative
Artistic, Aesthetic design	Scientific, Mathematical, Technical, Formal
Imaginative	Realistic
Daydreaming, Mind wandering	Working, Paying attention
Insightful (Aha Moments) Radical, Novel	Methodical, Incremental, Repetitive
Parallel, Simultaneous, Nonlinear	Serial, Sequential, Linear
Top-down, Holistic, Big picture	Bottom-up, Elemental, Detail-oriented
Scope, Scale, Context	Purpose, Objectives, Requirements
Open-ended, Adaptable	Closed-ended, Rigid
Integrative and Separative	Selective, Discriminative
Meta, Reflective	Iterative, Recursive
Generates (builds up and breaks down) and recognizes patterns, concepts, and ideas.	Manipulates, filters, and uses patterns, concepts, and ideas.
Processes Data↔Information.	Processes Data→Data and Information→Information.
Searches and finds possibilities.	Examines and executes goals.
Works across multiple levels of abstraction simultaneously.	Works within a single level of abstraction at a given time.
Synthesis (Blooms)	Analysis (Bloom's)
Intuition (Meyers-Briggs)	Thinking (Myers-Briggs)
Genius	Expertise
"Right brain", "Lateral thinking"	"Left brain", "Vertical thinking"
Default Mode Network (Neuroscience)	Task-Positive Network (Neuroscience)
Connectionism (Cognitive Science)	Computationalism (Cognitive science)
Neural Networks	(Can be compared to) Digital logic
Difficult to measure with tests. (See Creativity at Assessing individual creative ability)	Measured imperfectly by IQ tests.
Neurological capacity is largely fixed, but can be practiced to better use that capacity.	Neurological capacity (IQ) is largely fixed, but can be studied and exercised to better use that capacity.

Different way of thinking

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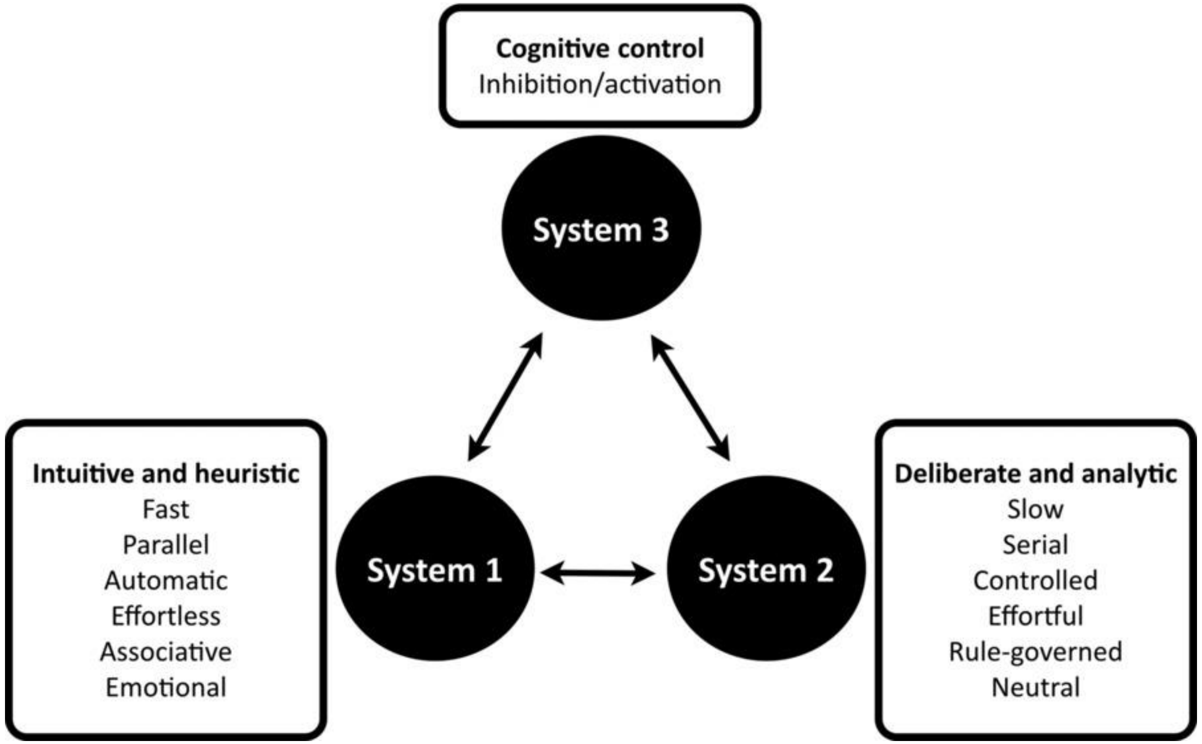
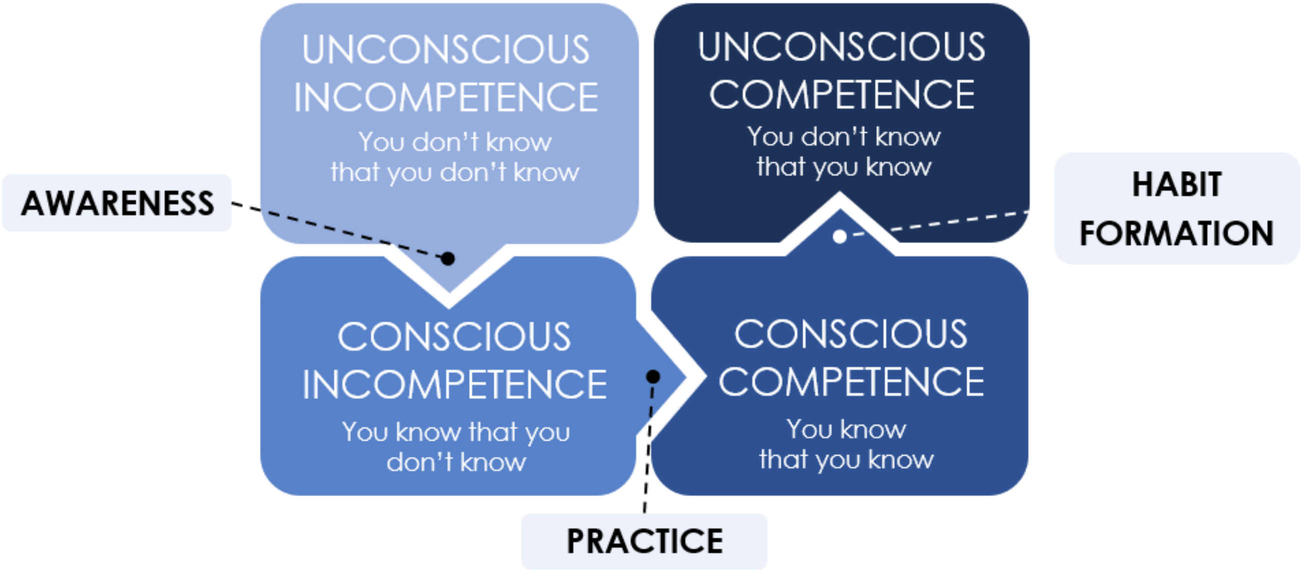


Cassotti, Agogué, Camarada, Houdé & Borst (2016)

System 1 may be where « skill » is ?

- System 1 is « Expert intuition », or simply recognition ?
- Picking up regularities in the environment ?
  - The important process of *Learning*



- But importantly: System 1 is also very often wrong and we can be totally unaware of it
- False beliefs, Incorrect heuristics, misjudgement are **subjectively undistinguishable** from « expert intuitions ».
- People tend to be overconfident about their own judgement
  - Overconfidence effect is one of the many « cognitive bias »

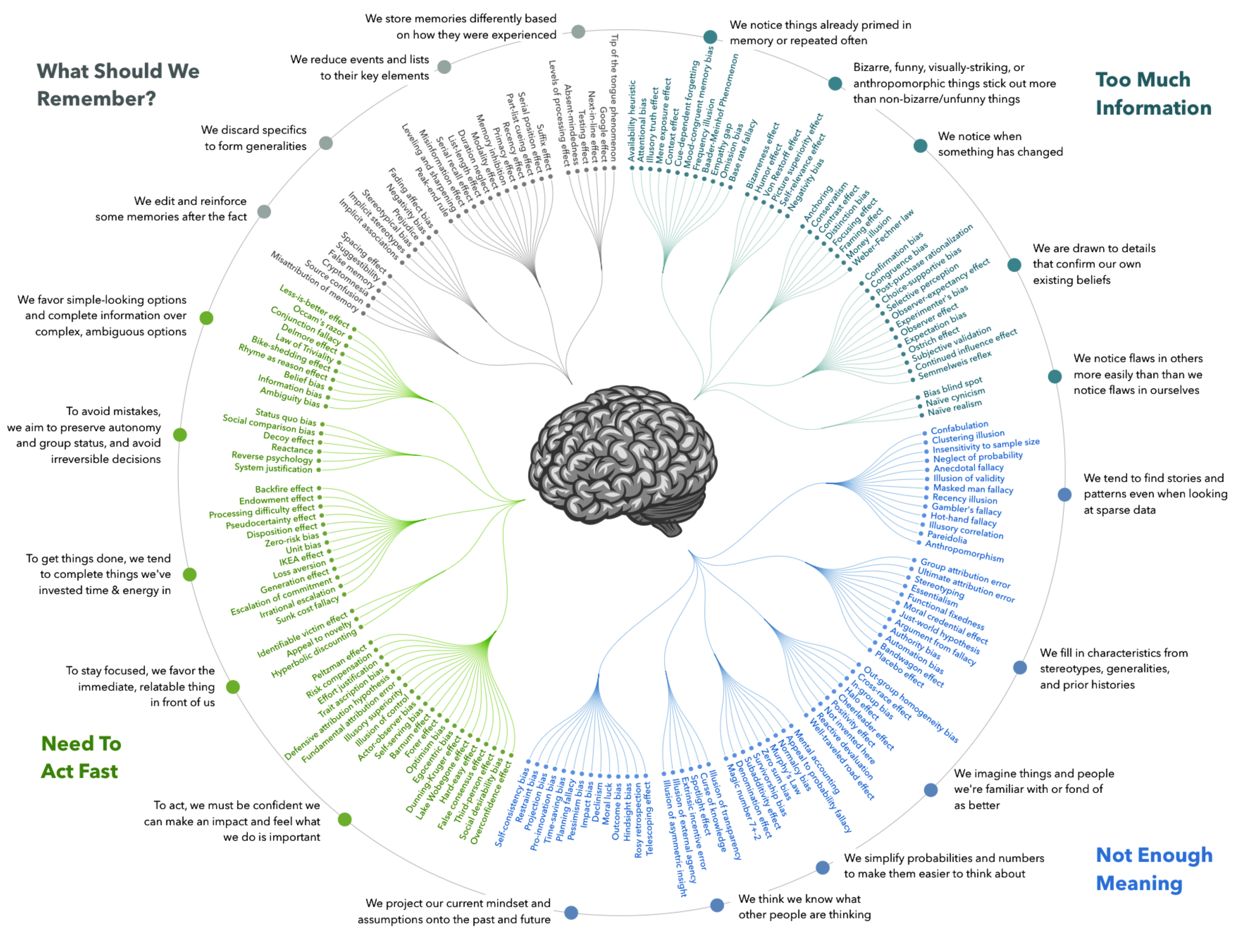
Typical cognitive biases

- Confirmation bias
  - we place extra value on evidence consistent with our favored belief.
- Hindsight bias
  - when we know the outcome, it is often hard to review prior events fairly with less acknowledgment of the role of chance (« I knew it all along »)
- Status quo bias
  - we prefer the status quo. This is especially a challenge in change management (preference for the current situation)
- Present bias
  - we prefer immediate rather than long-term gains
- Loss aversion bias
  - we feel losses more acutely than gains, making us more risk averse when considering losses than rational calculations would suggest

Typical cognitive biases

- Escalation of commitment and sunk-cost biases
  - future courses of action are disproportionately weighted on what we have already done leading us at times to continue to 'throw good after bad'.
- Fundamuntal attribution error
  - when in situations of conflict, we attribute our position to our context and the position of those we are in conflict with to their underlying personality, ignoring their context as being worthy of consideration. « explain behavior in term of personality traits »
- Anchoring bias
  - we root decisions in an initial value, whether it is fair or not.
- Controllability bias
  - we believe we can control outcomes more than we actually can, causing us to often misjudge the risks of an action.
- Outcome bias
  - we tend to over-reward the results of a decision and under-reward the quality of process used to make the decision. When things happen by chance, a risky poorly-made decision may now be over-valued and repeated in the future (and vice versa when a poor outcome by chance following a well-supported decision becomes undervalued).

COGNITIVE BIAS CODEX



DESIGNHACKS.CO · CATEGORIZATION BY BUSTER BENSON · ALGORITHMIC DESIGN BY JOHN MANOOGIAN III (JM3) · DATA BY WIKIPEDIA

Something **even more difficult** to process for the human brain - The Simpson Paradox

Treatment	Treatment A Chemical	Treatment B Surgery
Total	**83% (289/350)**	78% (273/350)

Small tumor	Group 2 87% (234/270)	Group 1 **93% (81/87)**
Large tumor	Group 4 69% (55/80)	Group 3 **73% (192/263)**

When looking at global numbers, Treatment A is better

When looking at small and large tumorsseparately Treatment B is better, even for both sizes (!)
And yes, all the maths are correct ☺

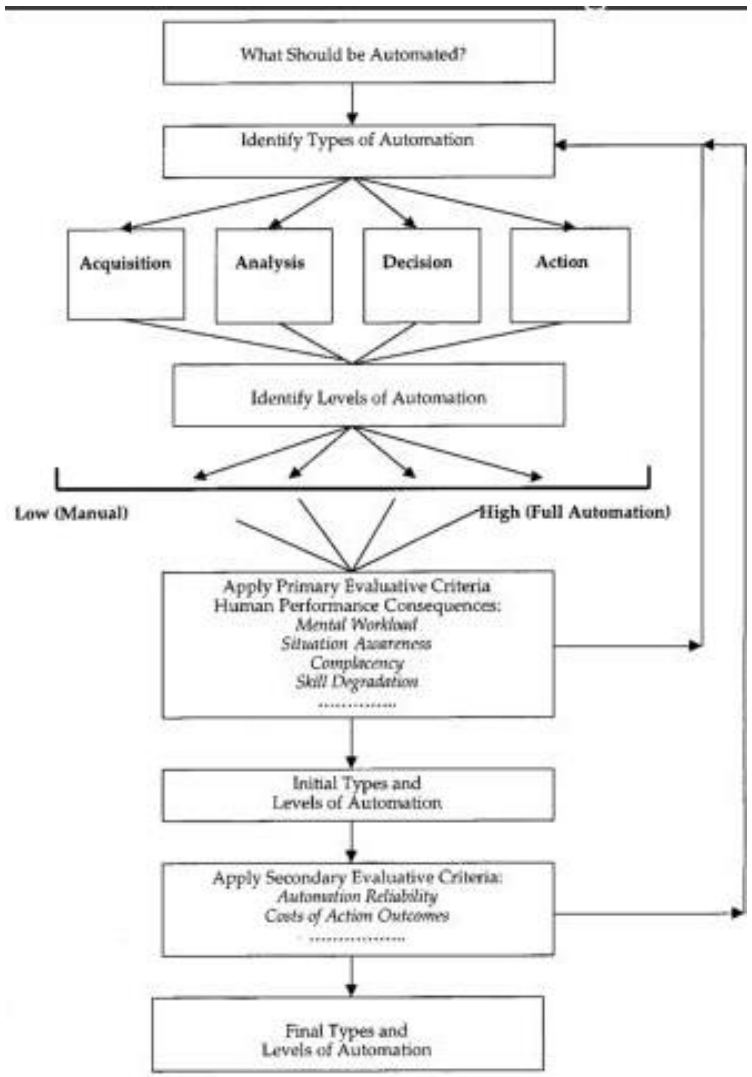
Human factors in system design

- What to automate ?

  ## Function & Task allocation

- Critical issue in Human Factor Research
- Applied methodology

- *« Because you can »* automate a task doesn't necessary means that you should !



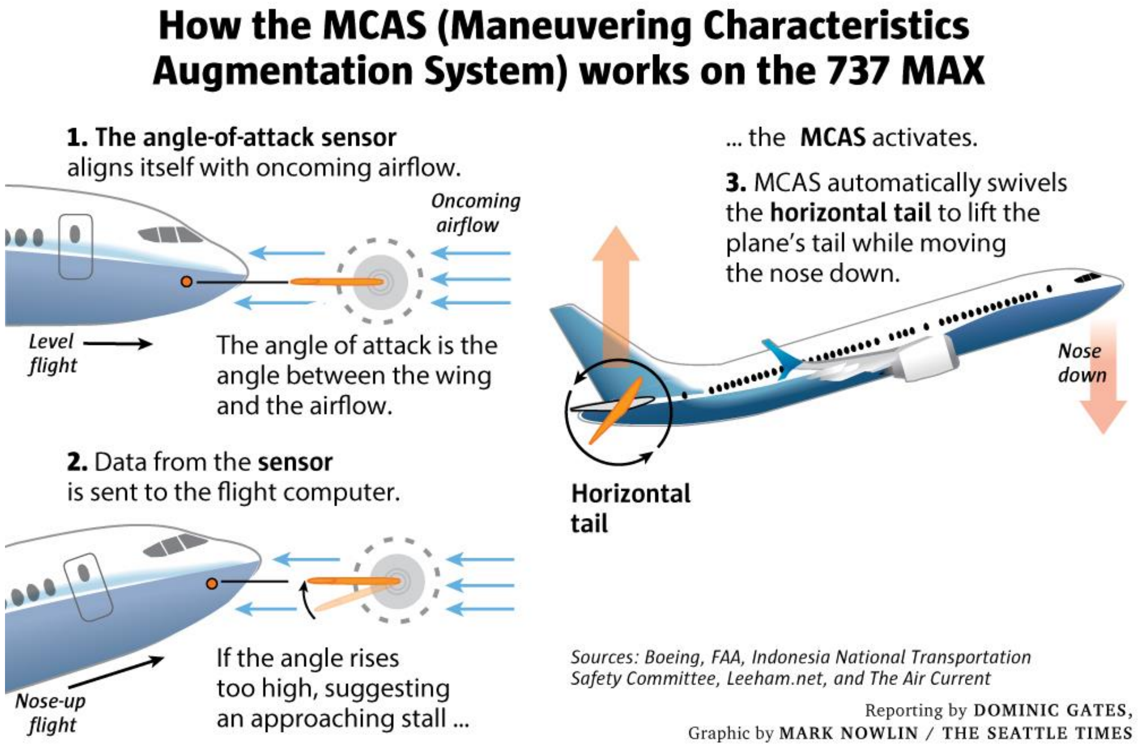
Pasuraman, Sheridan and Wickens (2000)

Example in aeronautics (when system are done wrong)

- Boeing 737 Max catastrophy
  2 crashs just after take-off
- Lion Air 610 (29 october 2018)
  - 181 passengers 8 crew
- Ethiopian Airlines 302 (10 mars 2019)
  - 149 passengers 8 crew

Major Causes :

- A too high level of automation
- Not enough sensors (2 for AoA)
- A too complex procedure to desactivate
- No pilots training in order to reduce costs…



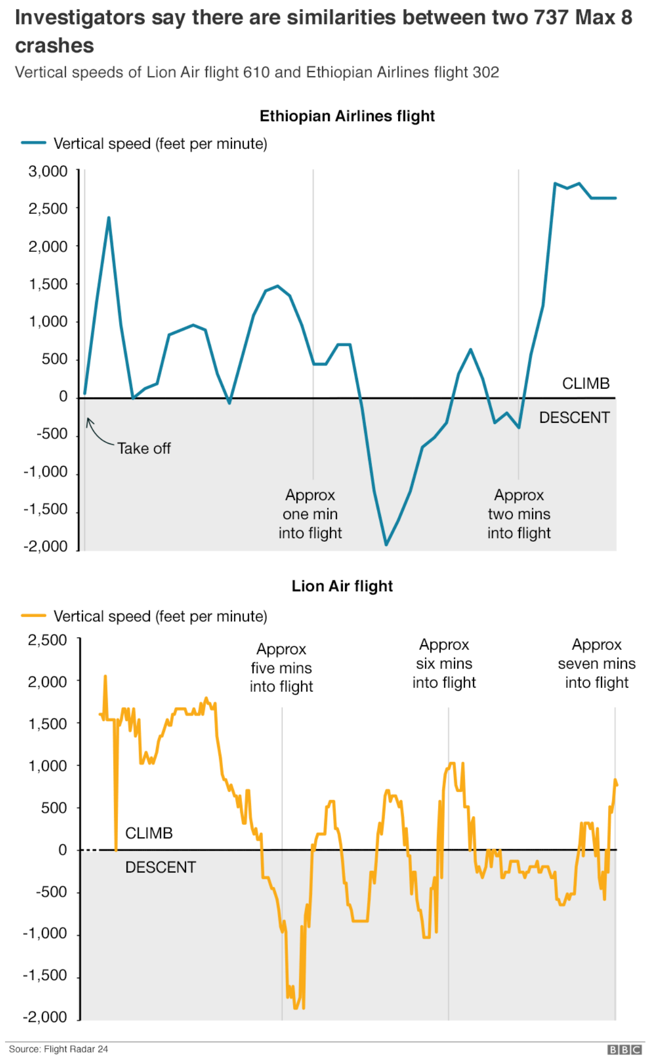
Example in aeronautics (when system are done wrong)

In Ethiopian Airlines 302, investigation revealed:

Pilots desactivated the system 12 times, but only temporarily

- Pilots unaware of 3 other steps:
  - turning off the motor controling the horizontal tail
  - confirmation step of turning the motor off on another switch
  - Turn a wheel manually to re-angle the plane's nose
- In Lionair 610, cockpit voice recorder revealed that the pilot was looking for 9 minutes in the intruction manual of the plane without finding the correct information

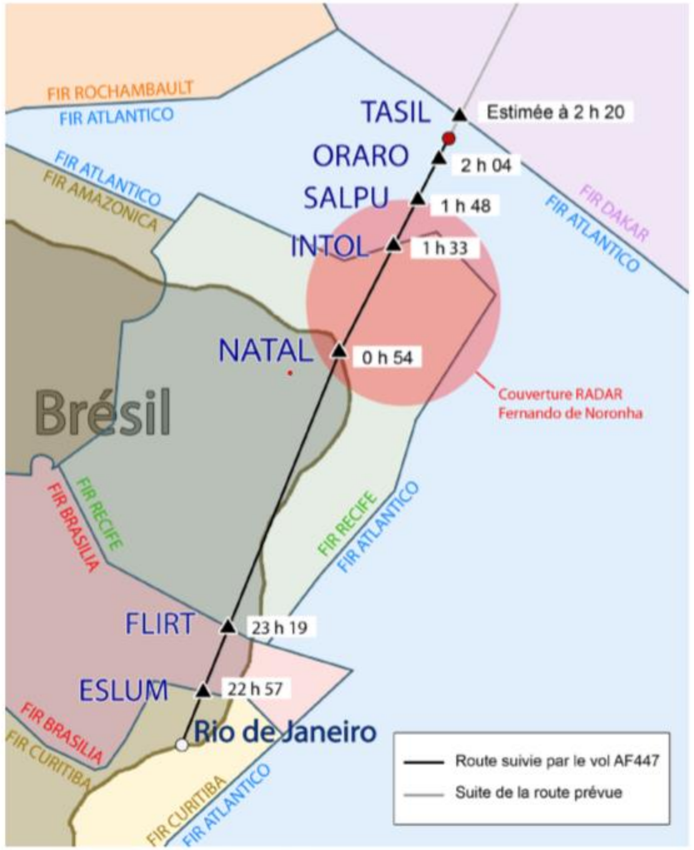
- Pilots struggled against the machine
- In that case, the computer wons...



Example in aeronautics (when human are doing wrong)

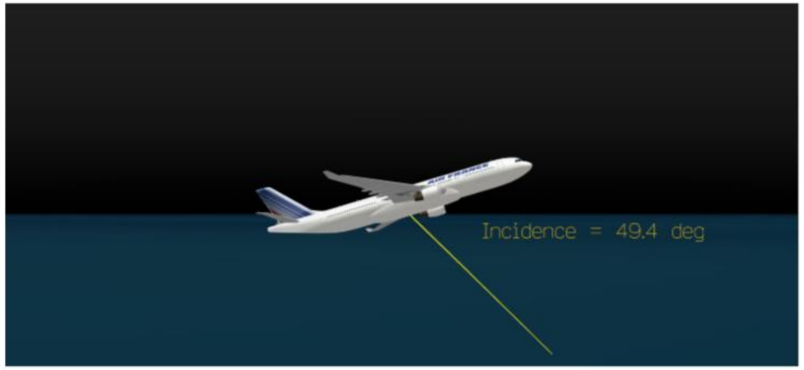
- Rio-Paris AF 447 catastrophy
  - 216 passengers, 32 nationality, 12 crew

- From sensor error… (Unreliable airspeed measurement because of incing of pitot sensors)
- …To human error (The pilots-in-control pulled back on the stick, thus increasing the ange of attack and causing the aircrat to climb rapidly
- The pilots apparently did not notice that the aircraft had reached its maximum permissible altitude
- The pilots did not read out the available data
- The Stall warning sounded continuously for 54 seconds (!)
- The pilots did not comment on the stall warnings and apparently did not realize that the aircraft was stalled (=really ??)



Possibles causes (Human Factor Investigations)

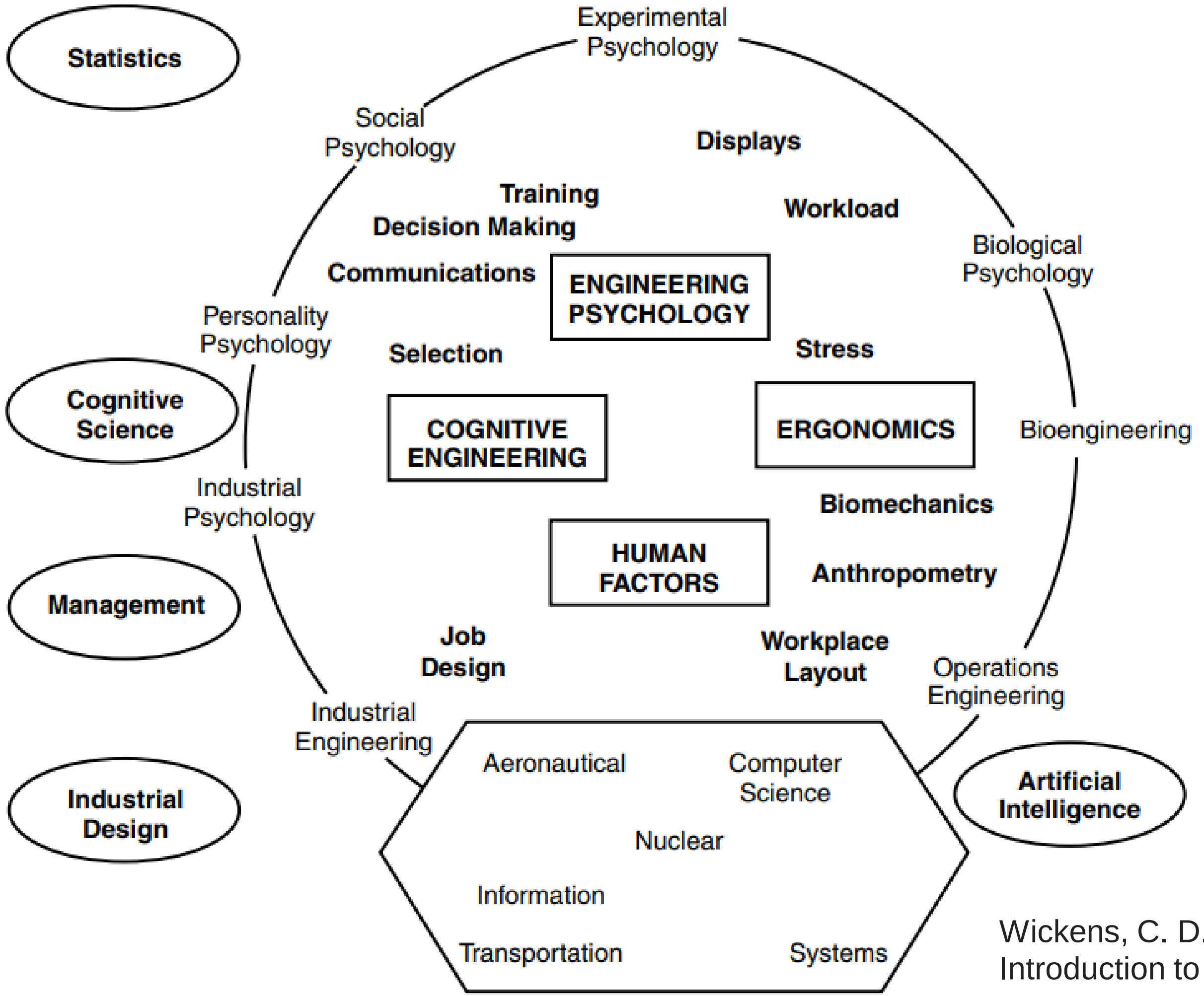
- The stall warning deactivates by design when the angle of attack measurements are considered invalid, and this is the case when the airspeed drops below a certain limit.
- In consequence, the stall warning came on whenever the pilot pushed forward on the stick and then stopped when he pulled back; **this happened several times during the stall** and this may have confused the pilots.
- Despite the fact that they were aware that altitude was declining rapidly, the pilots were unable to determine which instruments to trust: it may have appeared to them that all values were incoherent



Angle of attack of the plane in the last few seconds before crash

Human Factors and Ergonomics

- Interdisciplinary approach by essence, borrowing from many disciplines



Wickens, C. D., Lee, J., Uu, V., & Becker, S. G. (2004). An Introduction to Human Factors Engineering.

https://www.youtube.com/watch?v=9TIBeso4abU

Thanks !