Keynote

Cognition and Cognitive Processes

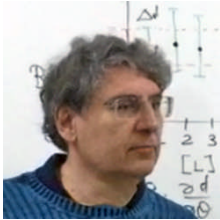## In the realm of Design, Science and Philosophy

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- Research interests:
    - cognitive science, cognitive systems design, complex adaptive systems, computational intelligence, philosophy of cognitive science

- Background:
    - BSc Electrical Engineering , BSc Physics, MSc Biomedical Engineering / Neuroscience, PhD Computer Vision

Cognition, Perception and Consciousness:
Logical and Structural Aspects

- Complex actions can be decomposed into elementary actions
    - So, it can be distributed along specialized effector organs
        - Arms, legs, feet, hands, fingers, …
    - Each one with its specific action control module
- Specific rules define the compositional manner by which these modules are linked
    - There's a kind of grammar ruling how to compose complex actions from single elementary ones.
- A "sentence" made through this grammar is a complex action
    - To be effective, the sentence must have a "meaning" suitable to each action context
    - So, sensory data must be encoded in correspondence to action meanings, must match the sensed context to the action context.
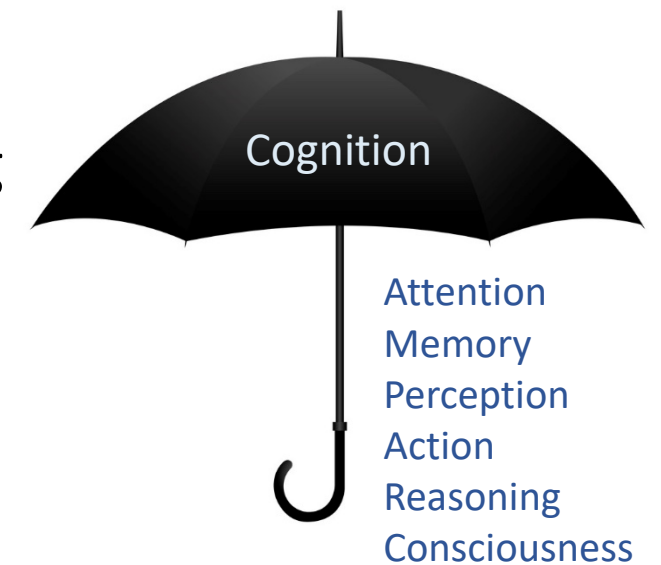
- More info:
    - Research:
        - https://www.researchgate.net/profile/Joao_Kogler_Jr

    - Professional activities (academic, consultancy, industry, organizations,)
        - https://www.linkedin.com/in/joao-kogler-9a83b41b/

The future of cognitive systems R & D

- Before asking about the future, let us ask what are we talking about – i.e., "what are cognitive systems ?"
  - The question about *what is cognition* is still in the agenda…
    - Although there are some proposals for a clear definition of cognition, they constitute exceptions among the R & D community
      - The proposals are frequently ignored
  - In turn, it is usual that cognition is taken as an "umbrella concept"
    - As a general property encompassing perception, memory, language, attention, action and behavioral control, consciousness,…
      - Even famous books like Posner's and Gazzaniga's adopt this view
  - Many use the term "cognition" as if it was an intuitive and obvious concept, maybe taking it as a "primitive term".
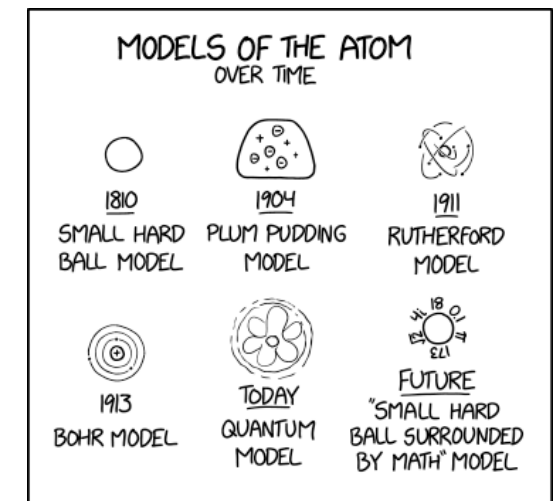
Cognition

Attention
Memory
Perception
Action
Reasoning
Consciousness

What is cognition ? is a relevant issue

Well, … what is an atom ?

- The question of *what is cognition* is still in the agenda
  - People are still interested in this matter, mainly young researchers
    - It is not very uncommon, however, to find students discouraged by their advisors from including a discussion on this subject in their dissertations.

- So, we are wondering about the future of something that we have not yet defined with sufficient clarity
  - Surely we don't have to stop everything just because of it. Nevertheless, one must consider the issue at the same time that R & D goes ahead
    - Consider its relevance and importance
      - Maybe try well justified ideas, like in the case of the conception of the atom…
        - The ideas can be discussed, confirmed, refuted or evolve

Edited image from xkcd comics

Or, maybe…
the 'flat atom' model
😊

Why does it matter?

- It affects the research of cognitive systems and the design of cognitive applications
  - Design of cognitive systems applications
    - At the conceptual design, architectural modelling, and testing steps
  - Research on cognition and cognitive systems
    - It delineates the targets for research efforts
  - Philosophy of mind and of cognition
    - It will influence a network of concepts, directly or indirectly derived, with many implications and consequences
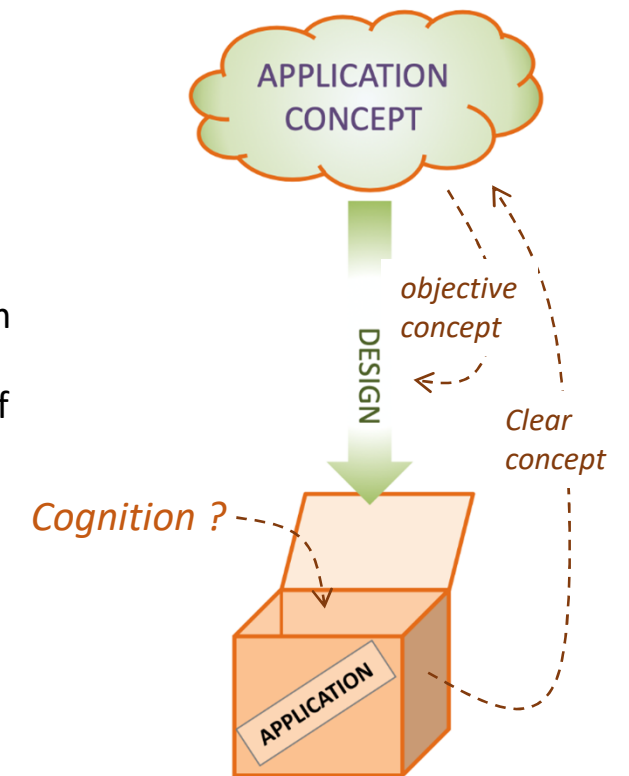
Standard steps on design:
- Conceptual analysis
- Concept specification
- Requirements analysis
- Requirements specification
- Architectural analysis
- Architecture Specification
- Detailed design
- Components specification
- Part list elaboration
- Prototype building
- Prototype test
- Product design
- Product deployment

Why does it matter… for Design?

- A clear and objective concept of cognition is important to the…
  - Design of cognitive systems applications
    - At the conceptual design, architectural modelling, and testing steps.
      - Any application starts with a conceptual design step, which in the case of a cognitive system means that one must justify the need for cognition in the application.
        - It must be explained why the use of cognition leads to the expected functionalities of the application, and
        - How cognition enables to achieve those functionalities
      - The conceptual design affects other design steps
        - The functional specification – one must describe the relations among the cognitive functions and the remainder of the system
        - The system architecture – is cognition localized in a module, is it distributed, is it embedded in specific parts, etc.
        - The application testing step – how to verify if the prototype is meeting the functional specifications
          - Case not, explain why, try to debug the prototype

APPLICATION CONCEPT

DESIGN

objective concept

Clear concept

Cognition ?

APPLICATION

Why does it matter… for **Research**?

DOESN'T MATTER WHAT IT IS AND HOW IT LOOKS LIKE, JUST FIND IT !

- A clear concept of cognition can be helpful for the…
  - Research on cognition and cognitive systems
    - It delineates the targets for research efforts
    - One can and have to proceed with research on cognition even not having a definitive or agreed conceptualization of it
      - However, some proposals or working definitions, models and hypotheses must precede any investigation on the subject
        - "What are we looking for ?" is the starting question in experimental research
        - '"What are we trying to explain" is the starting issue of theoretical considerations

Why does it matter… for Research?

Marr's 3 levels

- This relevance can be understood by means of Marr's methodological approach
  - It is applicable to any kind of complex system
    - Originally proposed by David Marr for research on visual perception
      - Can be applied in the case of cognition and cognitive systems research
  - The understanding of a complex system starts at the theoretical level
    - To formulate hypotheses and provide models for its explanation in conceptual terms → which must be provided or defined
      - A suitable theoretical explanation provides basis for the functional description of the system in terms of functions that operate on representations of the objects and their relations
    - Which can be mapped on their physical realizations

- **Theoretical level**
  - Hypotheses, models
- **Representational – Functional level**
  - Algorithms, functions, computations
- **Physical – Biological level**
  - Neurons, brain
  - Circuits, machines
  - Physical mechanisms

Why does it matter... for Publicity and Education?

- What are the common issues?
  - The term "cognitive" is pervading the artificial intelligence R & D community, business, publicity, communications media, education,...
    - "The cognitive" is the new hype
      - https://www.researchgate.net/publication/335210285_Cognitive_is_the_new_hype_word

    - The abuses of the term can be inappropriate
      - Generating misconceptions
      - Can lead to diversions and loss of time
        - Missing the target on research efforts and design methodology

    - A misconception that can be traced to a lack of a clear conceptual and philosophical account of cognition.
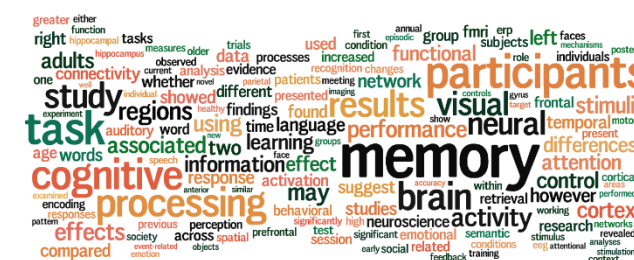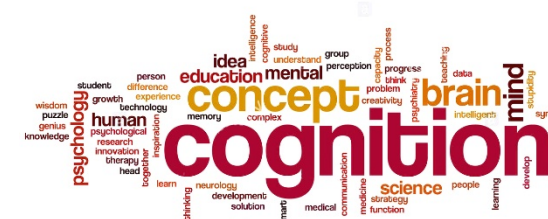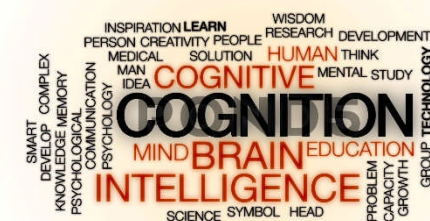
Why does it matter… for Philosophy?

- Philosophy studies cognition under the several aspects
  - Metaphysical, epistemological, axiological, and logical
    - There is some agreement that cognition has to do with information and knowledge
    - However, there are many schools of thought treating the issue of cognition in very distinct ways
      - In general they don't define cognition, and there are some that defends that cognition is not even definable.
      - They are more concerned with the ways how cognition happens
        - Two main groups of schools of philosophical thinking
          - Internalists → related to Cognitivism and Artificial Intelligence
          - Externalists → related to the 4E approaches (Embodied, Embedded, Enactive, and Extended cognition).

© ⟷ M **INTERNALISM**

C – cognition
M – mind
B – body
E -- environment

© M E B
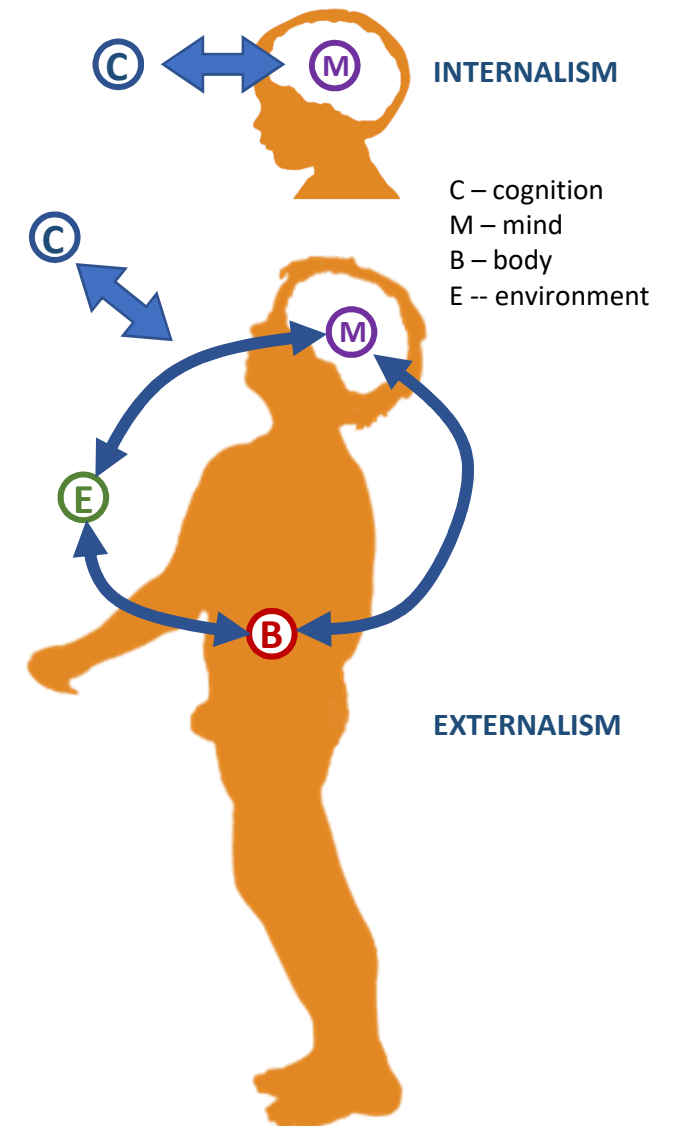
EXTERNALISM

The internalist's views in Philosophy

- For Internalists → cognition depends only on internal states, mind or brain states, through memory and sensorial snapshots of the environment

  - Sensorial information is registered , encoded and bonded by perception in separated perceptual units → the percepts
  - Percepts thus are proximal causes for cognitive states
  - The external world provides only distal influence over cognitive states
  - Cognition does not operate continuously over a direct stream of sensorial information (as does perception), but via a working memory

- It is taken by philosophers as the position of Cognitivists, Conexionists and Artificial Intelligence researchers
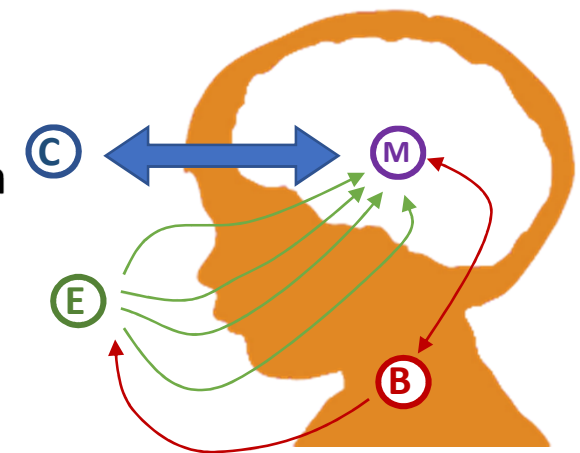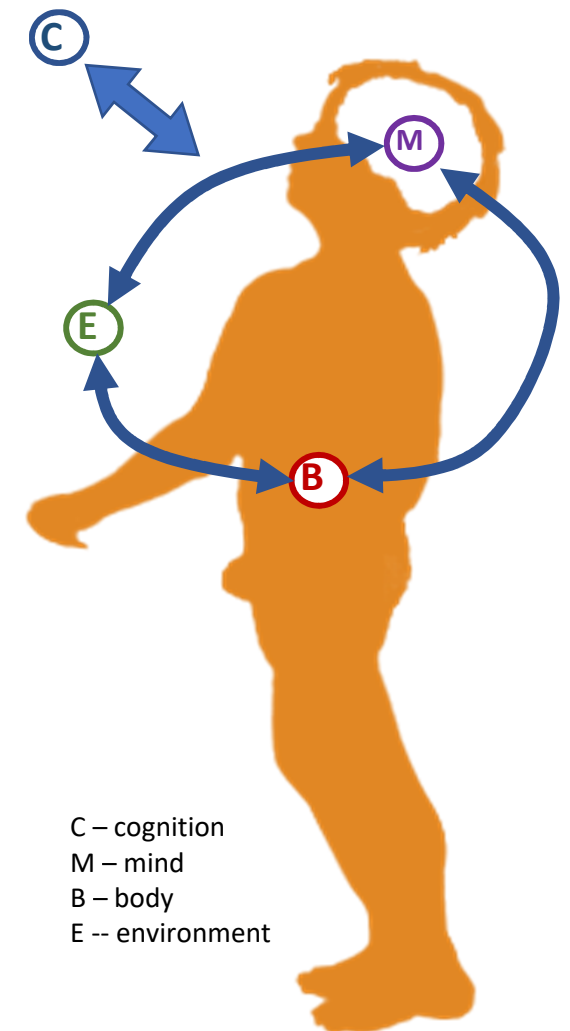
C – cognition
M – mind
B – body
E -- environment

The externalist's views in Philosophy

- For Externalists → cognition derives directly from mind or brain states, body states and environment states from a continuous information stream flowing between the nervous system, sensory organs, action effectors (organs capable of actions), and all body constituents, in coupling with the environment.

  - Sensorial information is registered , encoded and bonded by perception in continuous changing perceptual patterns.
  - Perceptual patterns are part of a continuous chain of causation forming a perception-action cycle.
  - The external world changes are also part of this causation chain, binding action effects to perception, via sensations.
  - Cognition operates continuously over this stream of information (as does perception), on a direct way, through the connections with the perceptual-action cycles involving the body and the environment.

- The extent of participation of the components of this causal chain over cognition depends on each school of thinking of externalist view.
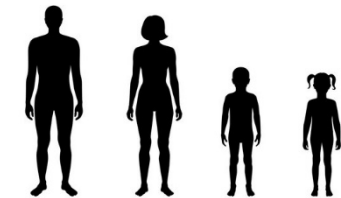
C – cognition
M – mind
B – body
E -- environment

The externalist's views in Philosophy – The 4E's

- **Embodied**
  - Cognition happens in the whole body
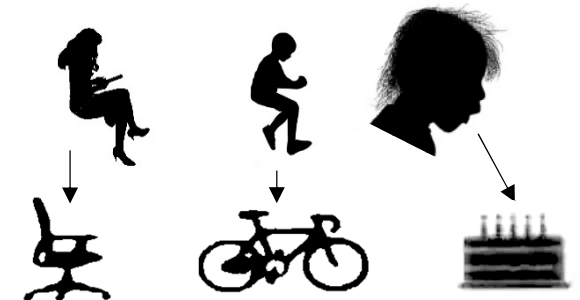   - It is not restricted to the brain.
- **Embedded**
  - Cognition happens also in the environment, through the offered affordances and interactions with the agent.
- **Enacted**
  - Cognition happens through chain of interactions among agents and the environment and through their continuous transformations over time..
- **Extended**
  - Cognition extends into the objects employed by the agent to perform actions.

Body →

Affordances →

En… actions →

Extensions →

What can we do?

- Avoid "umbrella concepts" and focus on the characterization of the phenomenon itself :
  - What is cognition? What are its characteristics?

- Describe cognition and the related phenomena: perception, reasoning, action, language, memory, consciousness, etc.
  - In terms of information processing, structure and dynamics
    - New tendencies are pointing to this direction, actually…

- What are the concrete prospective views for reaching such understanding?

What are the concrete prospective views for reaching such understanding?

- Provide working definitions of information processing terms related to cognition
    - Information, knowledge, meaning, representation, content …
    - Natural computations, grounding, enaction,

- Criticize and improve the terminology until a satisfactorily agreeable point

- Describe cognition, perception and related concepts using the above terminology

- Avoid the "*umbrelling*" effect
    - Distinguish cognition, perception, reasoning, attention, consciousness, mind, etc.

- Use the new concepts as starting point, as working terminology, hypotheses, models, etc.
    - Verify how they work experimentally, on research, for development, etc.
    - Share to the community for discussion
        - BTW, the community should be open for new concepts and proposals, stimulate the debate

In addition, will this help to better understanding the future directions?

- How?

  - At least there will be a clear direction to follow with R & D

  - Therefore, the question **Cognition: "*Quo Vadis*"** will make a new stronger sense

Keynote
Cognition and Cognitive Processes
In the realm of Design, Science and Philosophy

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cognition

attention
perception
action
memory
language
reasoning
consciousness
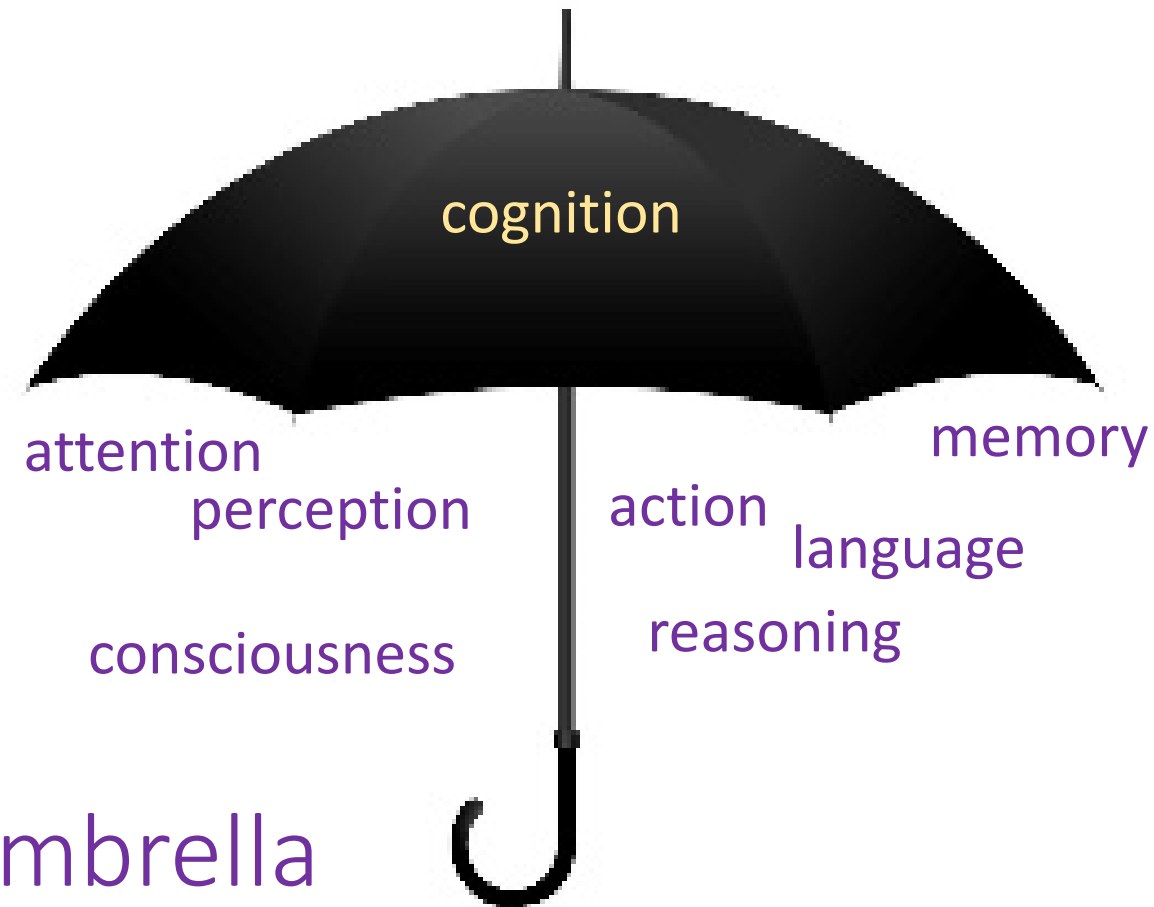
The Cognition umbrella
must change

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Cognitive processes

- Cognition   x   Perception
  - Both are informative processes →
    Deal with information
    - Information encoded from sensory data
    - Encoded in a way **suitable** for producing
      effective actions
      - **Suitable** in the sense of coping with
        action's own "language", or
        - **Understandable** by the action
          modules

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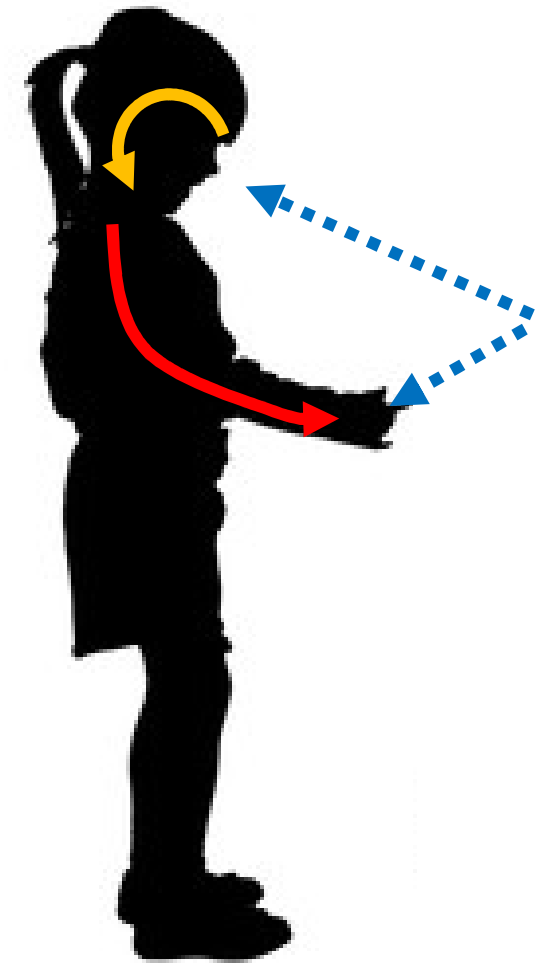
Cognition x Perception

- However, they differ under the logical and structural aspects
  - Perception **links straightaway** to action modules
    - It is **tightly committed** with efficiency in providing information to action effectiveness
      - Cope with structural and functional aspects of the action modules / organs
      - It must be fast, give quick results for the motor subsystem

    - Evolutionary standpoint→ prior to cognition, by hypothesis
      - The simpler the agent (animal) and its behavioral / ecological aspects, the simpler the perceptual scheme required

Cognition x Perception

- Cognition is the process of building and using knowledge
  - Knowledge is built by relating invariants
    - It's a long-term process
      - If relying exclusively on perceptual representations built from sensory data
    - It can be improved by recursively building over past knowledge

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Cognition x Perception x Language

- Properties of cognition, perception, and language
  - They are systems of processes
    - complex collections of processes
      - Called *cognitive processes*

- Cognitive processes characteristics
  - They deal with information invariants
    - Coding invariants → perceptual representations
    - Structural invariants → linguistic representations
    - Contextual invariants → knowledge (cognitive representations)

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Concept of cognition

- Cognition is based on cognitive processes
  - A cognitive process is a process that builds knowledge from information
  - But there's more about cognition…

- Cognition improves long term autonomous action
  - The agent executes the action…
    - … based on the available knowledge
  - The autonomy is of the agent
    - Observation: we refer here to operational autonomy
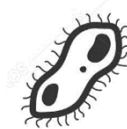   - Capacity of deciding its own actions based on information obtained by its own means.

Predictive capacity

Kinds of behavior

cognitive agents

intelligent

knowledge based

perceptive agents

adaptive / predictive

adaptive

reactive agents

reactive

AUTONOMY

purely reactive
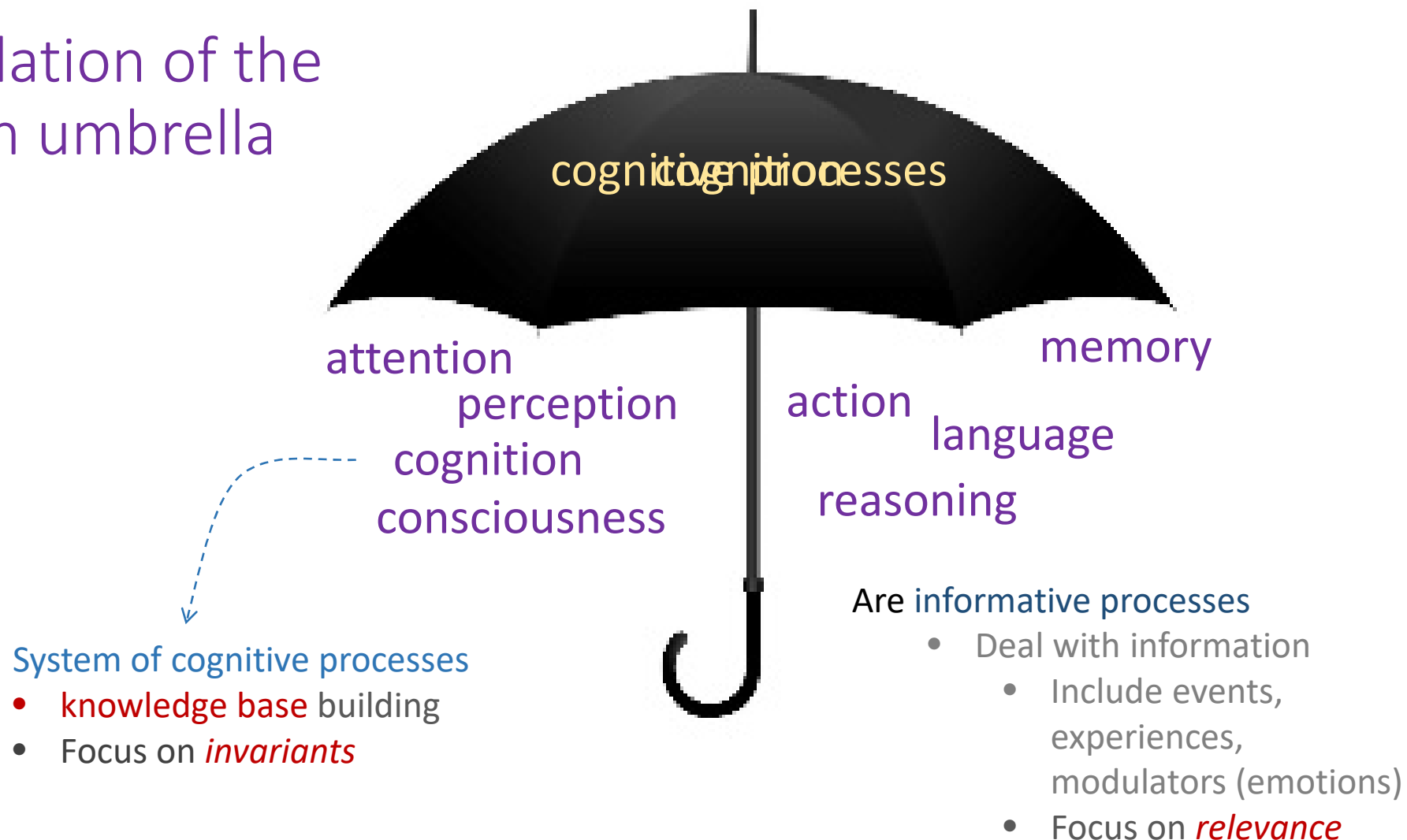
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Cognitive processes for cognition

- Knowledge
  - *Know* is the root of the word "knowledge"
    - It comes from the Sanskrit word *gnana*
    - *Gnana* also leads to the word gnosis → Greek word for "knowledge"
    - *Gnosis* leads to the Latin word *gnoscere* (to know, to learn) that led to *cognoscere* and *cognitio*

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Reformulation of the Cognition umbrella

cognitive processes

attention
perception
cognition
consciousness

memory

action
language
reasoning

System of cognitive processes
- **knowledge base** building
- Focus on *invariants*

Are informative processes
- Deal with information
  - Include events, experiences, modulators (emotions)
- Focus on *relevance*

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- Information-based conceptualization of cognition
  - Cognition
    - Cognitive Processes
      - Information
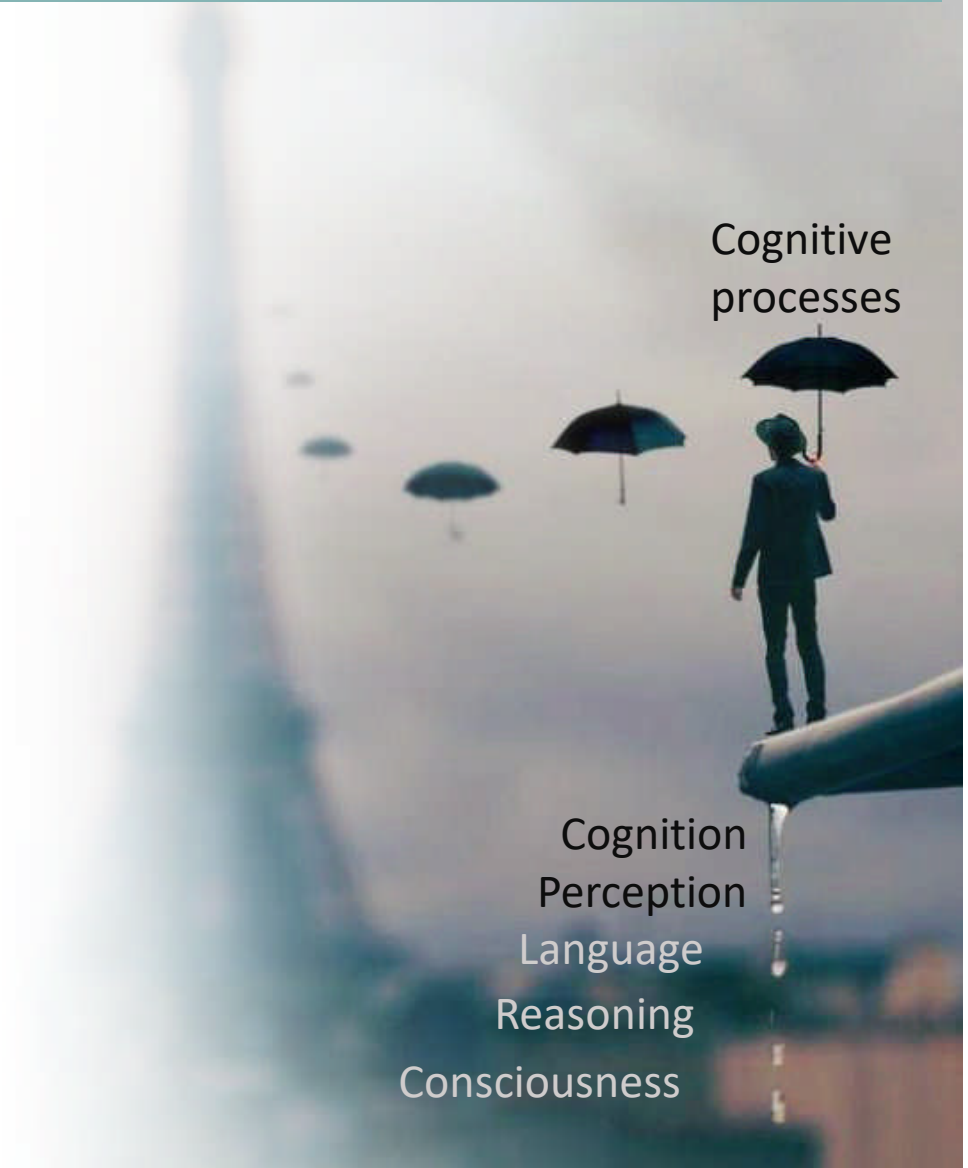
Cognitive processes

Cognition
Perception
Language
Reasoning
Consciousness

- # Information-based conceptualization
- ## Cognition
  - System of cognitive processes
    - ### Cognitive process
      - Process that extract knowledge and information invariants from data
        - #### Knowledge
          - Context-independent information
        - #### Information
          - Relevant data content
            - ##### Data
              - Receptor-encoded representation of observations of properties available to the senses / sensors
            - ##### Signals
              - Observations of physical properties available to the senses / sensors
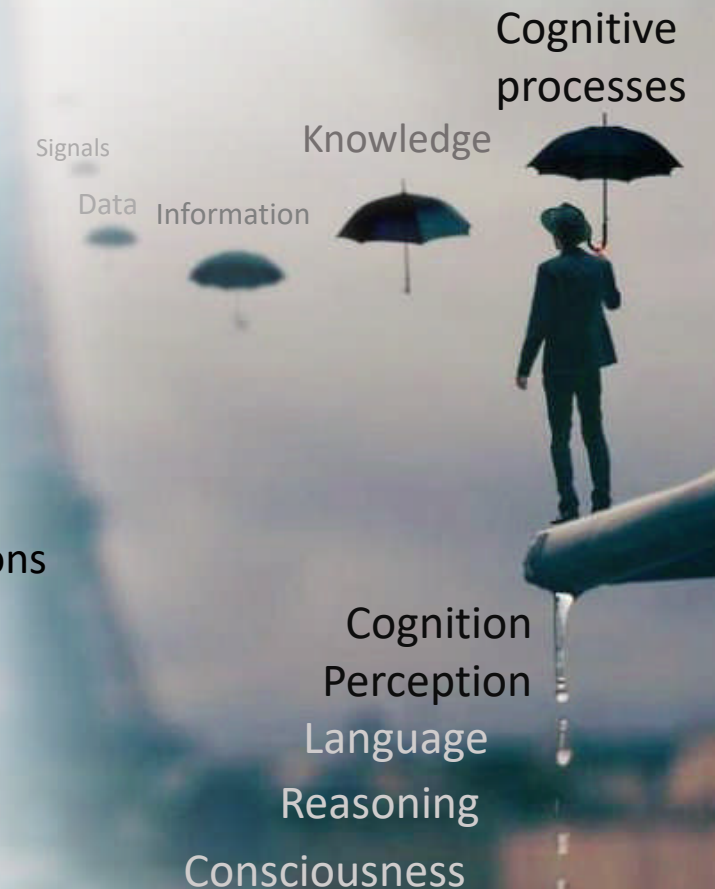
Cognitive processes

Signals

Knowledge

Data Information

Cognition
Perception
Language
Reasoning
Consciousness

- Information-based conceptualization
  - Cognition
    - System of cognitive processes

Remarks

- Not just any system, but of a kind with some extra and important functionalities:
  - System of cognitive processes that enables an agent to <u>build and use</u> knowledge, increasing the agent's autonomous behavior.
    - *Self-organized system of processes*

- Information-based conceptualization
  - Knowledge
    - Context-independent information

Remarks

- In order to avoid conflicts with the requirement of universality of knowledge (true justified belief)...
  - ... we adopt two classes of knowledge:
    - Local knowledge → built by the agent
    - Global knowledge → knowledge that copes with universality
    - Condition: local knowledge evolves to global knowledge
      - Via communication, critical reasoning, investigation, etc.

- Information-based conceptualization
  - Knowledge
    - Context-independent information

Remarks

- In what sense is it "context-independent" ?
  - Knowledge is information
    - Knowledge is information with meaning
    - Meaning associated to the *non-contextual* referent of the information
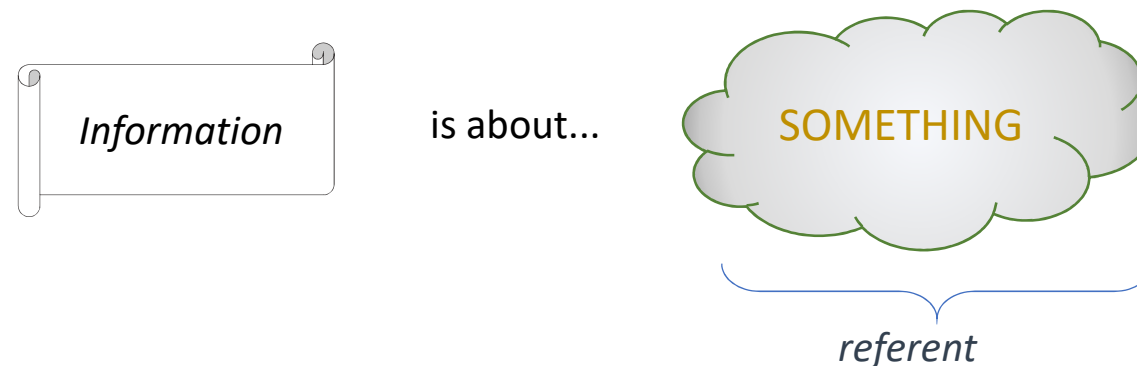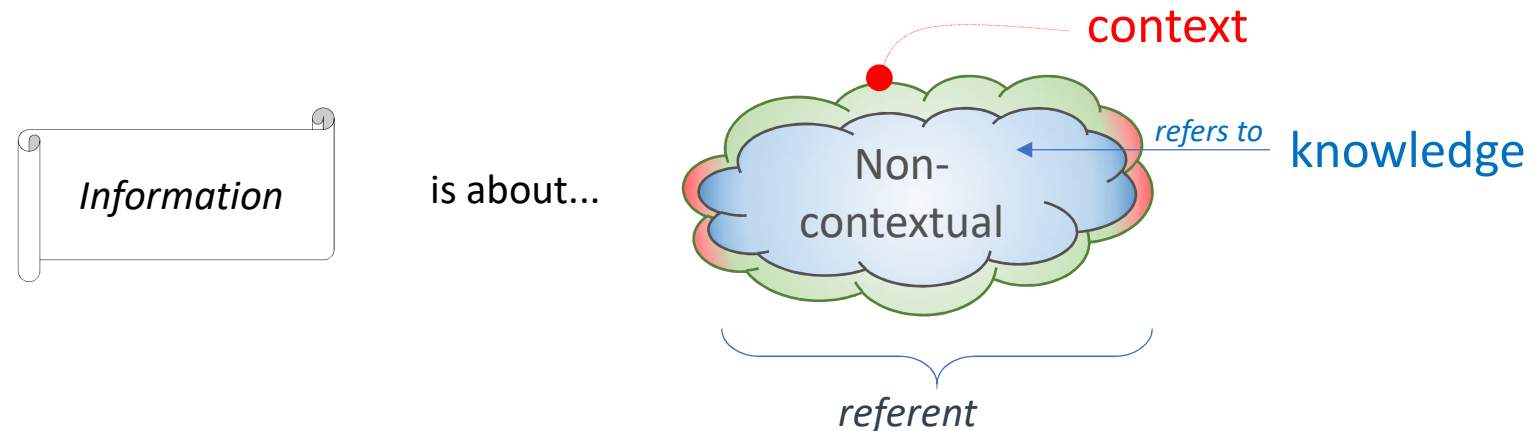   - Intrinsic or **semantic** meaning

Remarks (cont.)

- In what sense is it "context-independent" ?
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Information is about... SOMETHING
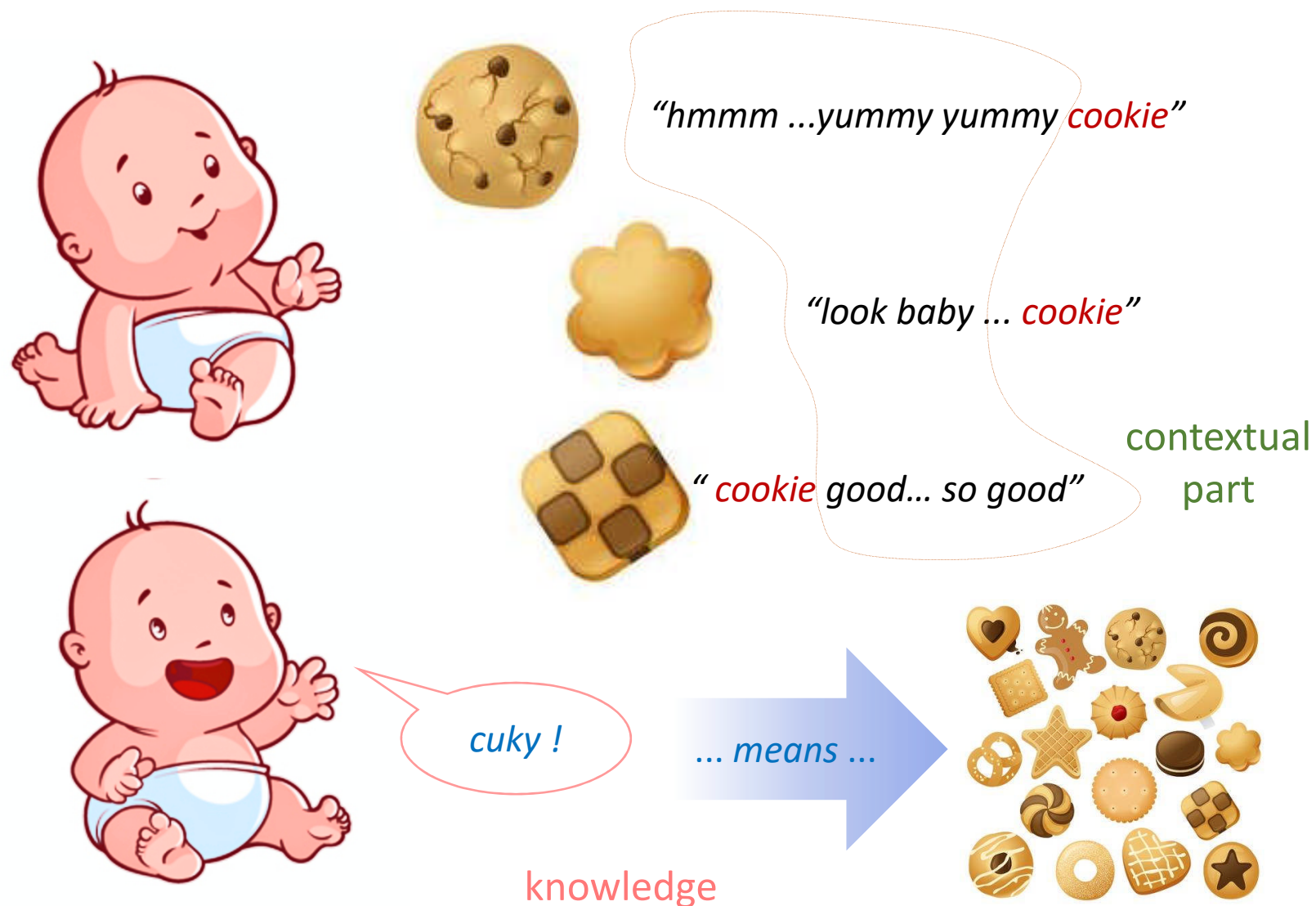
referent

Remarks (cont.)

- In what sense is it "context-independent" ?
  - Knowledge is information
    - Knowledge is information with meaning
    - Meaning associated to the *non-contextual* referent of the information
      - Intrinsic or **semantic** meaning

context

refers to

knowledge

Non-contextual

Information   is about...

referent

Concept of cognition

- Operational definition of cognition

  – Cognition is a system of processes that yield the build of knowledge and shape its use in order to improve the agent's operational autonomy.
    - The processes that build knowledge are the so- called cognitive processes.

- Consequences of the definition

  – To Design → how does it help.
  – To Research → is it a good *bridge principle* ?
  – To Philosophy → is it neutral among schools of thinking ?

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Cognition and Cognitive Processes
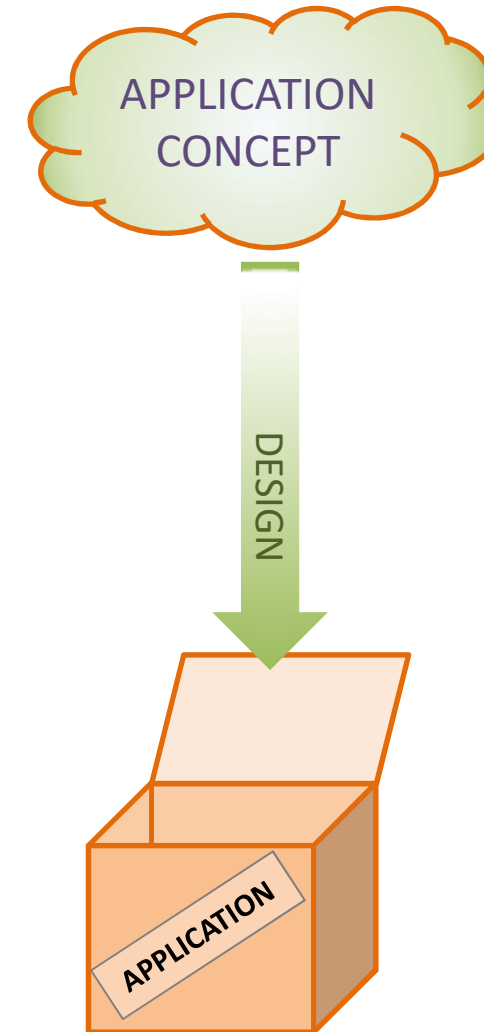In the realm of Design, Science and Philosophy

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Consequences to Design → how does it help ?

- Standard steps on Design
  - Conceptual analysis
    - Objective → what for ?
    - Uses / functions → how ? What is does ?
  - Requirement Analysis
    - Functional / operational requirements
  - Architectural Analysis
    - Functional structure → (cognitive) architecture
  - Design Procedure
    - Design specification → choice of methods
    - Components / Part list
    - Project formalities → contract, deadline, costs
  - Prototype Building
  - Prototype Test
  - Product design / deployment

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APPLICATION CONCEPT

DESIGN

APPLICATION

- Standard steps on Design
  - Conceptual analysis
    - Objective → what for ?
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WHAT COGNITION IS

APPLICATION CONCEPT

DESIGN

APPLICATION
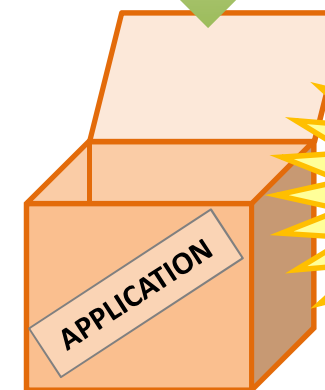
We need an operational definition of cognition

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Concept of cognition adapted for Design

- Operational definition of cognition
  - Cognition is a system of processes that yield the build of knowledge and shape its use in order to improve the agent's operational autonomy.
    - The processes that build knowledge are the so- called cognitive processes.
- Cognitive system
  - Is a system that builds knowledge.
  - We propose that there are two kinds of cognitive systems
    - Capable of autonomous actions → cognitive agents
   - Not capable of autonomous actions → cognitive tools

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Cognitive Systems

- Two kinds of cognitive systems
  - Cognitive agent
  - Cognitive tool

- Cognitive agent
  - The agent is the entity capable of executing action
  - If the agent is capable of build the knowledge required to execute the autonomous action → cognitive agent
  - Otherwise it is a non-cognitive agent

- Cognitive tool
  - Is a cognitive system (builds knowledge) that doesn't execute the actions (based on the knowledge it has built)
  - The cognitive tool provides knowledge to an agent to act.
    - This agent can be cognitive or non-cognitive.

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Example

What are the essential differences
Between situations A and B ?
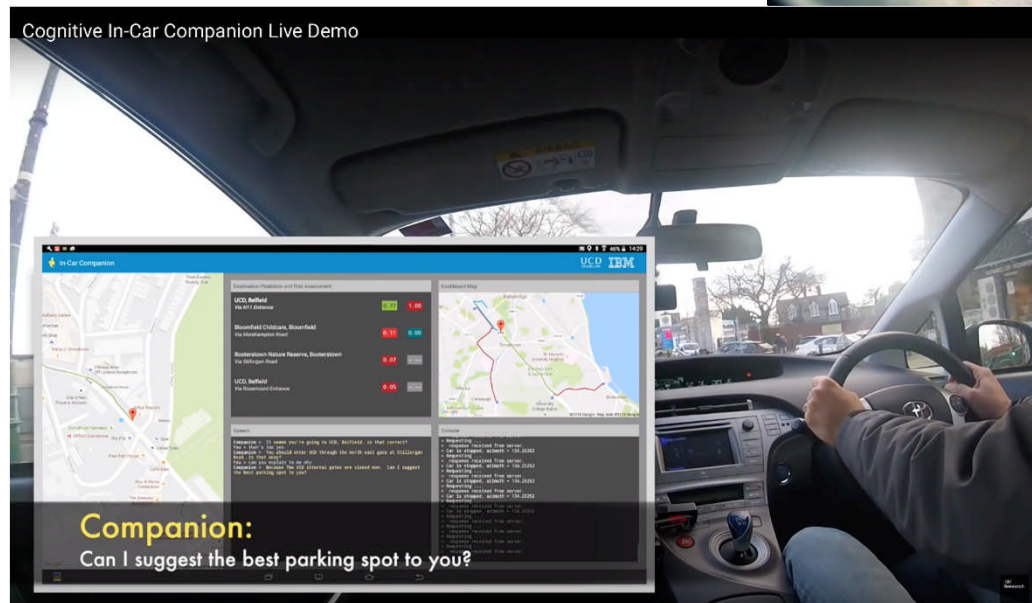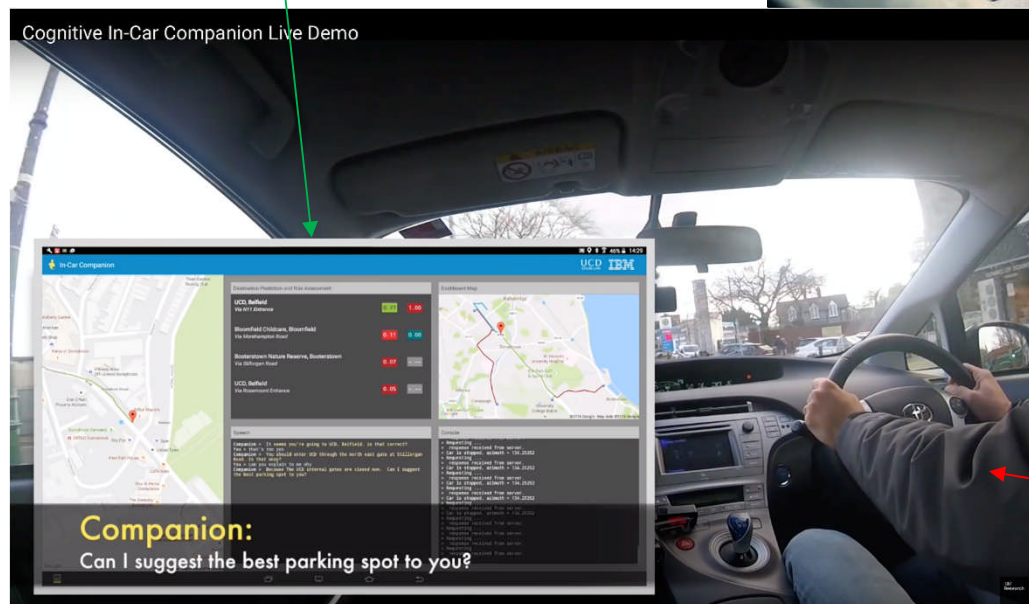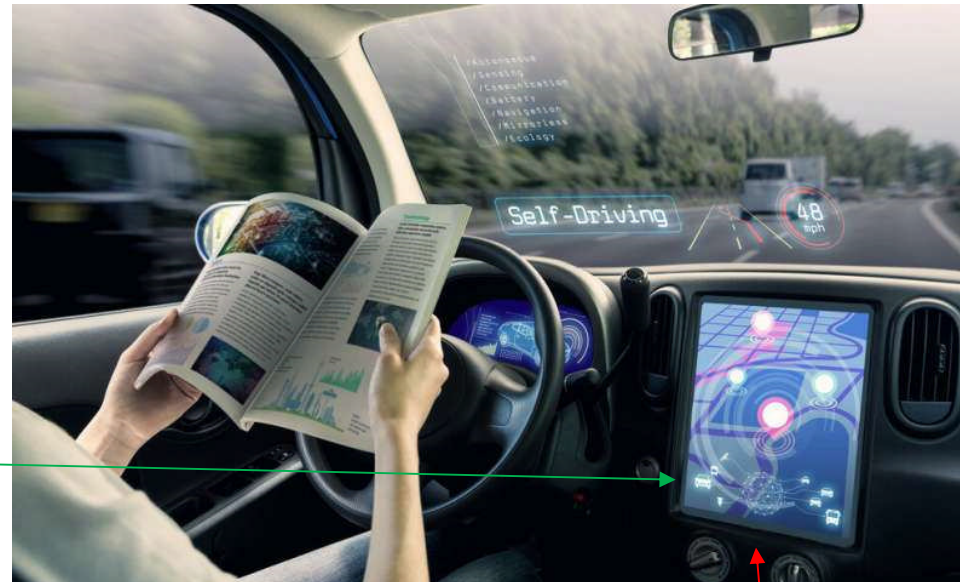
Situation A

Situation B

Images credits:
 IBM Research - Ireland and University College Dublin

Example

What are the essential differences
Between situations A and B ?

Situation A

Knowledge source

Images credits:
 IBM Research - Ireland and
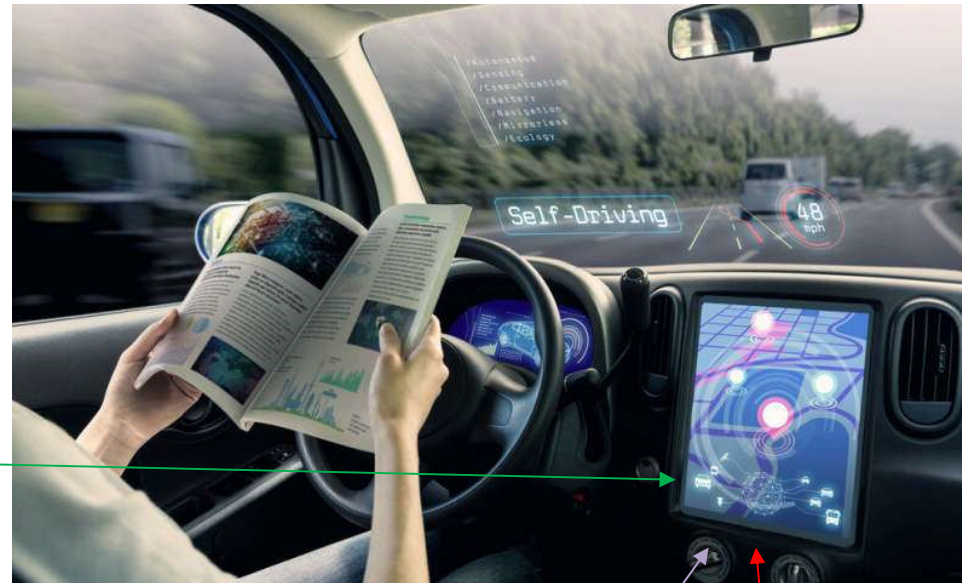University College Dublin

Situation B

Driving agent

Example

What are the essential differences
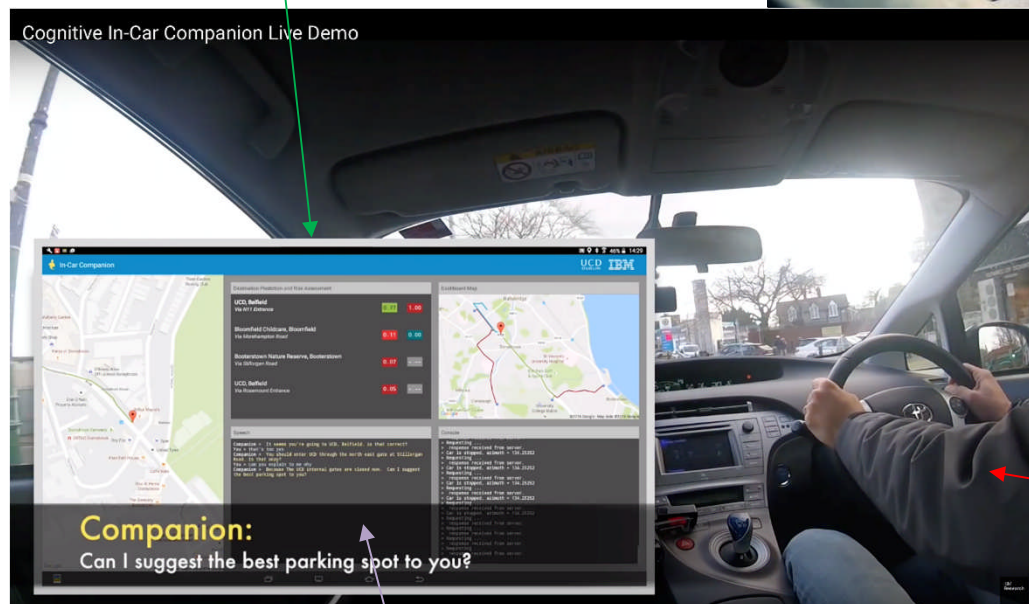Between situations A and B ?

Situation A

Knowledge source

Cognitive agent

Images credits:
IBM Research - Ireland and
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Situation B

Driving agent

Cognitive tool

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Consequences to Research → is it a good bridge principle?

Bridge principles

psychological

- Reductionism   -   Nagelian reduction - Nagel (1961)

  - Translation between two theoretical vocabularies

    – Bridge principles or laws

  - Psychological states P1 and P2

    – P1 → P2

  - Biological states B1 and P2

  - Bridge laws (correlations)

    – P1 ← → B1
    – P2 ← → B2

  - Reduction

    – B1 → B2

  – The bridge laws lead to an *identification* between correlated states

bridge

The neural basis of
cognitive processes
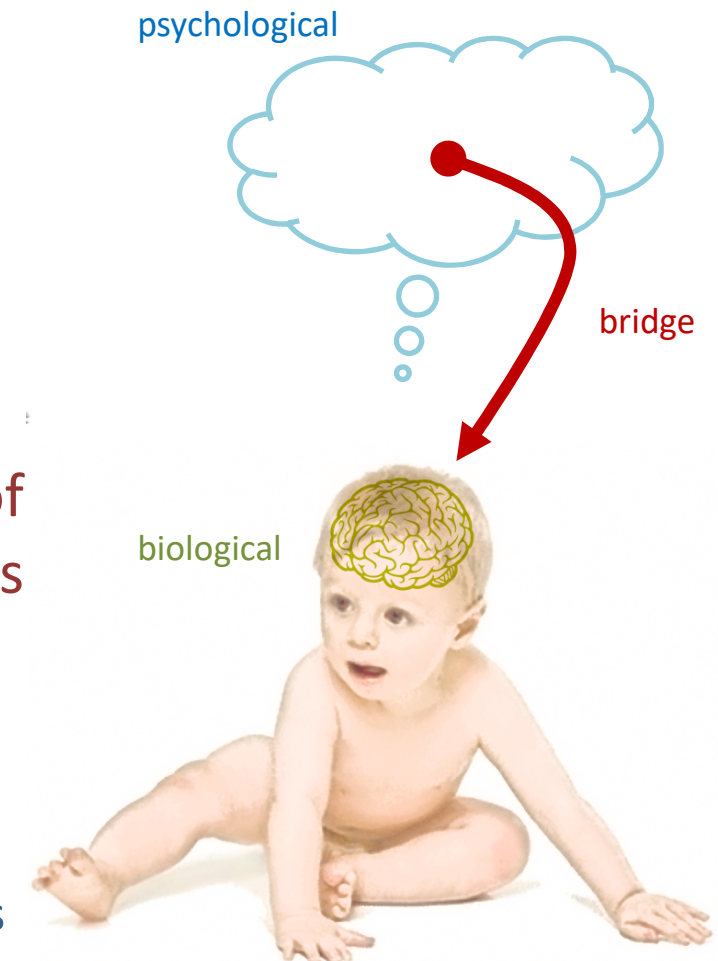
biological

Is our definition of cognition a good bridge law ?

- It is based on information-theoretical concepts only
  - Which are currently present both in psychological and neurophysiological descriptions
    - The concepts are stated in a precise way, linking physical properties to signals, signals to data, data to information, information to knowledge and knowledge to cognitive processes, with a very standard terminology.
  - It avoids common-sense uses of the terms, that usually pervades psychological descriptions
  - Thus, it provides a better way to bridge the gap between those areas, improving research perspectives.

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Consequences to Philosophy → Is it neutral among the schools ?

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Is our definition of cognition neutral enough ?

- For internalism
  - The definition is based on precise information-theoretical concepts, which can naturally replace or complement the information-processing terminology characteristic of internalist discourse, without difficulty.

- For externalism
  - The definition is neutral, because it will not replace anything, given that externalism does not define cognition or cognitive processes, but only the ways they are manifested.
  - Besides, by substituting cognition with cognitive processes at the top of the hierarchy of fundamental processes, the 4E's will apply directly to cognitive processes in a far more natural way , opening a new perspective for unifying the character of cognition among the distinct schools.

So, through this work I intend to understand the idea behind the umbrella, unveiling its principles and structure, to show that one can really say more about cognition and several mental features without recurring to obscure terms and mystifications.

Besides, that it is possible through universality, to design systems based on these findings.

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Thank you !

Cognition and Cognitive Processes

In the realm of Design, Science and Philosophy

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