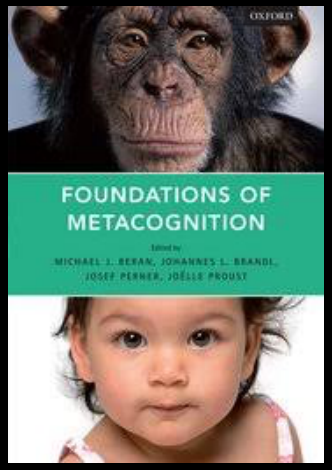
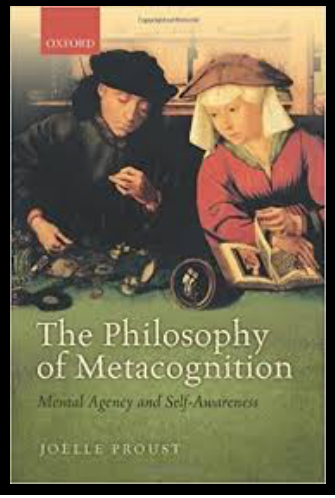
University of Nantes

Animal cognition Workshop
October 19-20, 2018

Non-human metacognition and intentional content





Joëlle Proust

http://joelleproust.org

Institut | Nicod

Nonhuman metacognition

The experimental study of nonhuman metacognition offers new avenues to the study of intentional content

This talk will summarize the scientific state of the art and propose a theoretical framework for

- ✓ explaining evidence of metacognitive abilities across species
- ✓defending the notion of evaluative, affect-based representationsl

Outline

1. Control and monitoring of bodily and cognitive action: definitions
2. Nonhuman metacognition: evidence and implications
3. Informational processes underlying metacognition
4. From implicit heuristics to conscious affordance-sensings
5. Conclusion: Thought awareness in non-humans has two dimensions

1. Control and monitoring of bodily and cognitive actions: definitions

Action

- Def: Trying to attain a given desirable goal through exerting voluntary control over properties in the world, including one's own body, and/or over one's own cognitive properties

- Cognitive action: trying to attain an informational goal (a cognitive change in one's own thoughts) through exerting voluntary control over one's own thought processes.

Control is inherent to action

- Performing an action would be impossible without a control system.
- Control has to do with
  - Appreciating the desirability of a goal appropriate to a given context
  - Selecting a command appropriate to this goal
  - Maintaining one's attention to the goal until completion
  - Deciding to stop the action before or when goal is attained

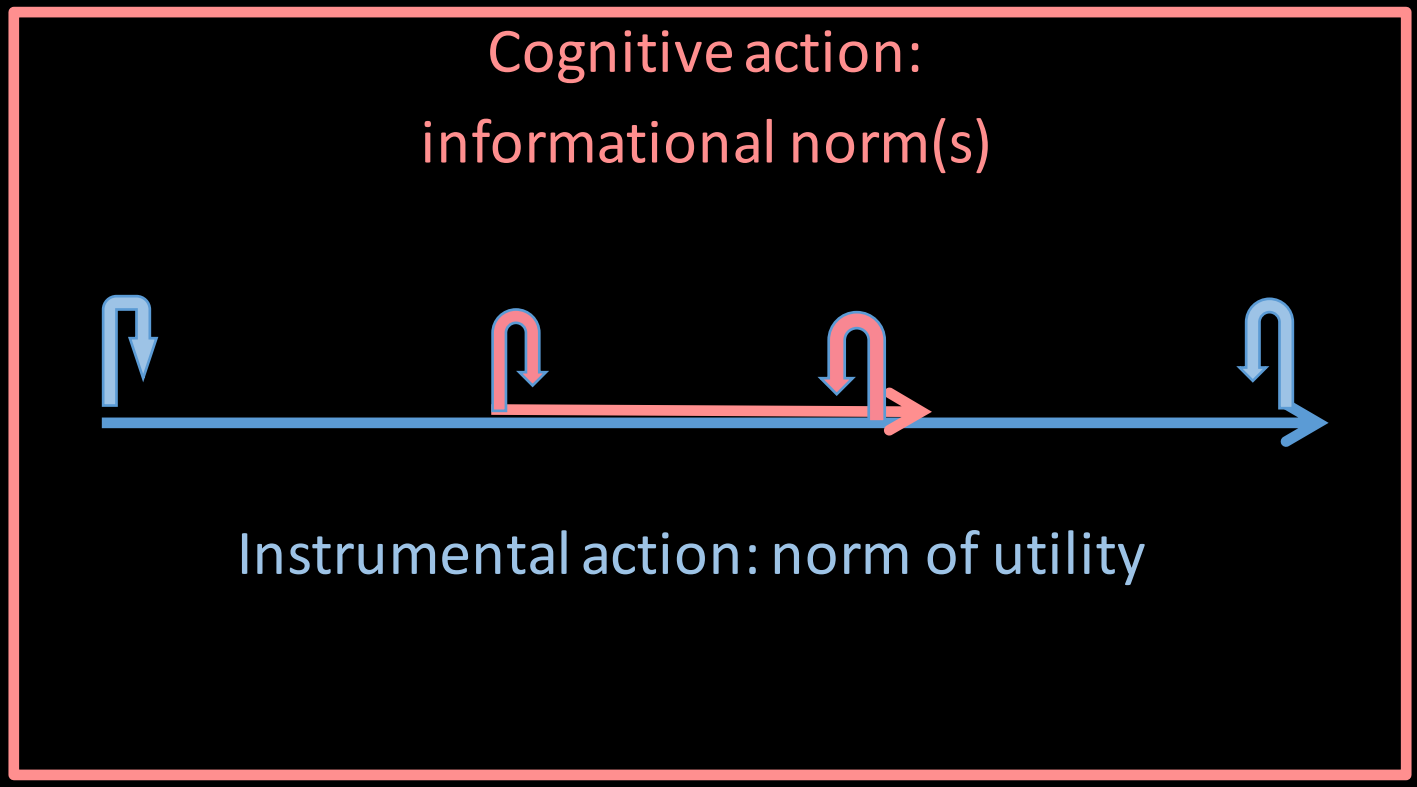
Control in turn requires a monitoring system

- Functions of monitoring = predicting and evaluating current activity
  - **Appreciating the feasibility** of a goal appropriate to a given context
  - **Predicting correct completion of intermediate steps of the action** (allows detection of error even before the incorrect step is selected)
    - Method: Detecting predictively discrepancies between anticipated vs observed feedback through comparators.
  - **Detecting environmental or internal changes** requiring action correction (in trajectory, in goal).
  - **Evaluating observed versus desired final outcome**
    - Method: detecting process discrepancies through a comparator.

What distinguishes "physical" and "cognitive" action?

- **The type of goal**: change the world/acquire or manage information
- **The type of control:** the range of actions available (motor/cognitive)
- **The predictive feedback** used: sensory feedback/neural, proprioceptive and interoceptive as well as sensory.
- **The norms** involved in action monitoring (instrumental/epistemic)
- **The constitutive/non-constitutive** role of norm sensitivity in performing the action

A cognitive action is based on two types of norms



Mental actions, in humans, are controlled and monitored by two kinds of information

(Koriat & Levy-Sadot, 1999)

- **Experience-based** metacognition uses feedback derived from the action itself (it is "activity-dependent")
- **Concept-based** metacognition consists in verbal or observational knowledge gained outside action, and possibly learnt from others.

"Experience-based" metacognition is the ability to

Control occurrent cognitive action

e.g.

- Try to discriminate a perceptual pattern from another
- Try to remember where the food was located
- Try to solve a problem

- Terminate a cognitive action

Monitor occurrent cognitive action

e.g.

- Feeling of easy/uneasy discrimination

- Feeling of knowing
- Feeling of ease/difficulty
- Feeling of being right/wrong

Koriat & Levy-Sadot (1999)

Function of procedural metacognition

Is to allow agents to collect reliable information

- By way of specialized conscious "noetic feelings"
- Based on implicit (nonconscious) predictive heuristics and decision thresholds that are constantly recalibrated.

Are nonhumans able to act cognitively, that is, to monitor cognitive actions ?

2. Non-human metacognition: evidence, implications

Main types of tasks used to test nonhumans' sensitivy to their own informational states

- Seeking for information (SI) tasks:
  "ask for information" only when needed (Call & Carpenter, 2001)
- Buying hints when learning (Kornell, Son, & Terrace, 2007) .
- Choose-or-decline-to-respond (« opt out ») paradigm (Smith et al., 2006, Beran et al. 2010)
- Wagering tasks (betting on correctness of a given response after it has been made).
- Moving to get reward based on internal confidence feedback (Beran et al. 2015)

Smith and/or coll. on metacognition in monkeys

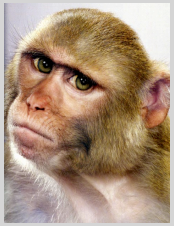
- Rhesus monkeys decline most the most difficult trials in visual discrimination tasks (Shield, Smith & Washburn, 1997) and in memory tasks (Hampton, 2001).
- They generalize their U- responses to new tasks. (Washburn, Smith & Shields, 2006)
- Macaques also use U-responses with blocked feedback (Beran, Smith, Redford & Washburn, 2006)

Sparse

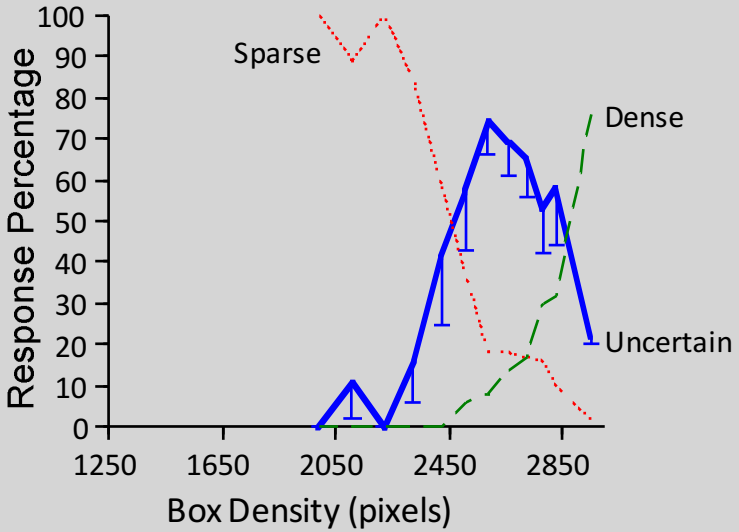
Dense

+

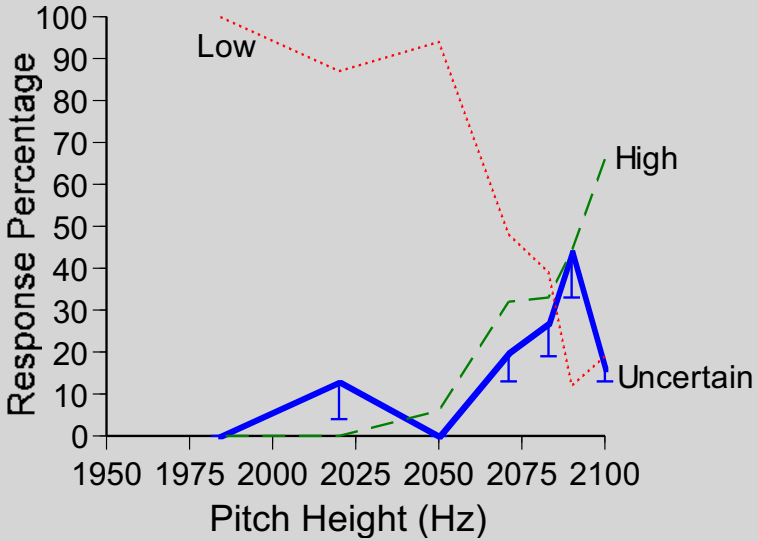
Uncertain

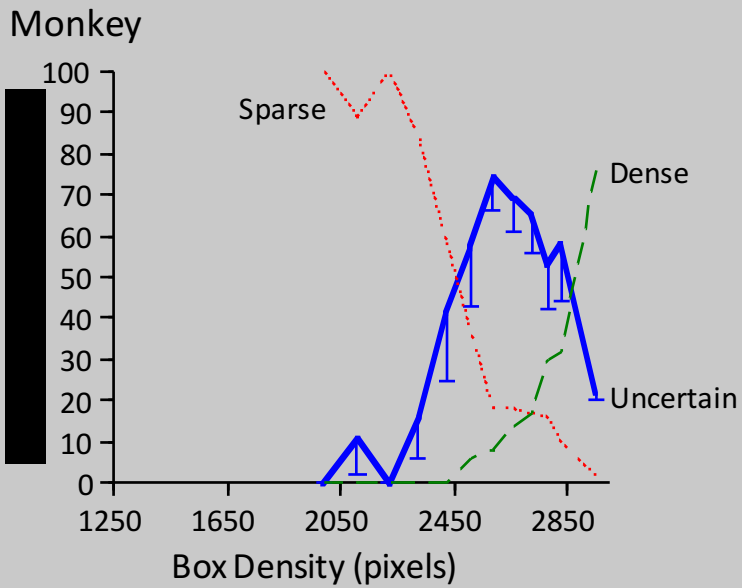


Macaque



Dolphin




Monkey
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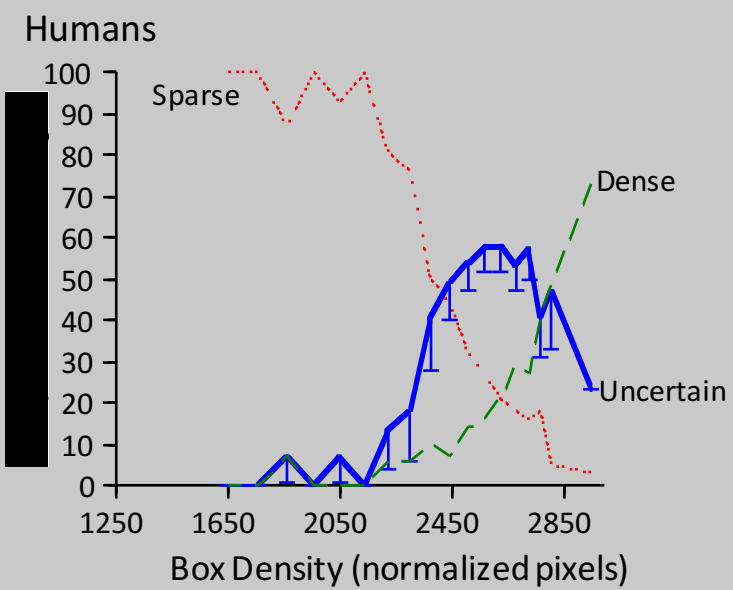
Box Density (pixels)


Humans
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2450
2850
Box Density (normalized pixels)

Metacognition in Phylogeny

Initially negative

- **Pigeons** no U-R (Sutton & Shettleworth, 2008)
- **Rats:** Smith & Scholl (unpub.), Smith et al. 2007 (no U-R)
- **Capuchin monkeys:** no SI, no U-R (Beran et al. 2006)

Finally positive

- **Pigeons** U-R opt out (Adams & Santi 2011)
- **Rats:** Foote & Crystal (2007); Kepecs et al (2008) U-R
- **Capuchin monkeys:** U-R (Fujita 2009)
- **Rhesus macaques** (SI & U-R) (Smith et al, Kornell, Hampton))
- **Bottle-nosed dolphins** U-R (Smith)
- **Chimps and orangutans** (SI) and UR (Suda-King 2008)

U-R= Uncertainty response

SI: Search for information

Some examples of non-human metacognition

- Monkeys evaluate whether they can reliably classify a cloud of dots as dense or sparse relative to a criterion
- Rodents know whether or not they can reliably remember what stimulus was associated in prior presentations with the probe.
- Chimpanzees know when they have correctly performed a task in a trial.

Evidence for experience-based metacognition in young children

- **20-month:** Goupil, Romand-Monnier & Kouider (2016)(non-verbal request for information)

- **3 yr-olds:**
  - Balcomb & Gerken (2008), (metamemory)
  - Paulus, M., Proust, J. and Sodian, B. (2013) (metamemory).
  - Bernard, S., Proust, J., & Clément, F. (2015) (metaperception).

Implications of the evidence

- Presence of metacognition in nonhumans suggests that it does not depend on mindreading, i.e. the capacity to attribute mental states to oneself.

- It rather depends on a procedural, i.e. nonconceptual ability to control and monitor one's own cognitive abilities, such as perception and memory.

Nonhumans' ability to control their first-order cognition (i.e., to act cognitively) raises two questions

1. What are the informational processes engaged?

2. Do these processes crucially involve subjective experiences?

3. What are the processes underlying animal metacognition?

Processes claimed to be used for cognitive control and monitoring in nonhumans

MAIN ALTERNATIVES

a. Based on reinforcement learning?
b. Only executive, goal-directed abilities?
c. Metarepresentations?
d. Specialized heuristics for predicting cognitive outcome?

SIMILAR/DISSIMILAR to human mc processes

Dissimilar

Similar

Processes claimed to be similar or dissimilar across humans and nonhumans: 4 mains views

a. ~~Based on reinforcement learning~~?
b. Only executive, goal-directed abilities?
c. Metarepresentations?
d. Specialized heuristics for predicting cognitive outcome?

a. Incompatible with experimental findings

Processes claimed to be similar or dissimilar across humans and nonhumans: 4 main views:

a. ~~Based on reinforcement learning~~?
b. ~~Only executive, goal-directed abilities?~~
c. Metarepresentations?
d. Specialized heuristics for predicting cognitive outcome?

a. Incompatible with experimental findings
b. Reward sensitivity independent from mc

Processes claimed to be similar or dissimilar across humans and nonhumans

a. ~~Based on reinforcement learning~~?
b. ~~Only executive, goal-directed abilities?~~
c. ~~Metarepresentations?~~
d. Specialized heuristics for predicting cognitive outcome?

a. Incompatible with experimental findings
b. Reward sensitivity independent from mc
c. No mindreading in monkeys

Processes claimed to explain metacognition in humans and nonhumans: 4 mains views (Proust, 2017)

a. ~~Based on reinforcement learning~~?

b. ~~Only executive, goal-directed abilities?~~

c. ~~Metarepresentations~~?

d. Specialized heuristics for predicting cognitive outcome?

a. Incompatible with experimental findings

b. Reward sensitivity independent from mc

c. No mindreading in monkeys

d. Behavioral studies and neuroscientific evidence converge.

"Traditional" unconscious heuristics used in humans' metacognitive monitoring

- Cue familiarity: elicited by the terms of the question (Reder, 1987)
- Overall accessibility of pertinent information regarding the target: elicited by the activity triggered by the question (Koriat, 1993)
- Fluency heuristic: responses that come to mind quickly are deemed correct. (see priming experiments as a source of confidence enhancement: Kelley & Lindsay, 1993)

Recently discovered activity-dependent heuristics

- Predictive neural dynamics: Kepecs & Mainen (2012).

- Predictive interoceptive cues from the respiratory, circulatory, digestive, and endocrine systems: Barrett & Symons (2015), Park & Tallon-Baudry (2014).

- In humans: Proprioceptive (postural, facial) cue-based heuristics.

Eskenazi, T.,Montalan, B., Jacquot, A., Proust, J., Grèzes, J. & Conty, L. (2016). *Quarterly Journal of Experimental Psychology.*

Informational source of heuristics in nonhumans and humans

Not thought **content**, but the dynamic signature of the neural **vehicle**:

- Processing onset,
- intensity (amplitude of activation)
- coherence of cognitive activity over time
- Latency to reach threshold (fluency)

together predict likely cognitive success of a given decision.

(Kiani & Shadlen, 2009,Kepecs & Mainen, 2012).

4. Do these informational processes involve intentional contents?

From implicit heuristics to conscious affordance-sensings

Kent Bach 1978: "representational causalism"

- Bodily acting relies **on two sets of executive representations:**
  - **Effective representations** provide the commands,
  - **Receptive representations** provide feedback for correction or termination of the process.

- **Executive representations**
  - are **not** propositional
  - not necessarily **linguistically coded**
  - nor do **they necessarily imply any intentions or beliefs**. (Bach, 1978, 366)

Executive representations for mental actions?

- Acting cognitively similarly might be claimed to rely on two sets of executive representations:
  - **Effective representations** provide the commands, for example:

    trying to remember a name

  - **Receptive representations** provide feedback for (i.e. monitor) correction or termination of the process; for example,
    - The agent feels that she can reliably retrieve the name that she is searching
    - The agent feels that the name she retrieved is correct.

Explaining nonhuman & human experience-based metacognition

- Involves characterizing the relation between
  - Nonconscious predictive heuristics
  - Conscious feelings
  - Decision and action guidance

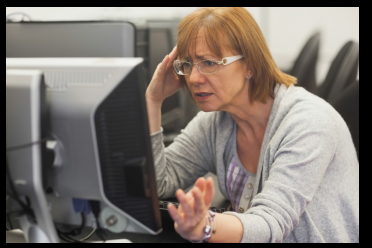
- Hypothesis: **All these elements** are part of an evaluative attitude, called an **affordance-sensing.**

- The notion of control and monitoring, recent conceptual research on affordances and empirical work on metacognition, however, now suggest that executive and receptive indicators are tightly **combined** in structured predictive representations.

Acting requires **minimally** a sensitivity to one of two types of "**affordances**":

- Opportunities & risks in the environment: **world affordances**

- Opportunities & risks in information acquisition/retrieval: **cognitive affordances** (Proust, 2013, **2015**, 2016)



As the word "affordance" suggests,

- Such an attitude has the double function of **detecting opportunities and acting on them.**

- An AS is a **conscious, non-propositional attitude whose function is to detect and evaluate** the opportunities and risks present in an agent's current environment.

- **On these attitudes: see philosophers Cussins (1992), Dreyfus & Kelly (2007), Gendler (2008), Griffiths & Scarantino (2009), Proust (2015), Strawson (1959), and psychologists Gawronski & Bodenhausen (2006).**

Differentiating the two kinds of affordances

- Evaluating likely reward in bodily acting on a given opportunity (sensing a **world affordance**)
- Evaluating likely cognitive success in cognitively actng on a given opportunity (sensing a **cognitive affordance**)

Depend on different sources of information and are processed by distinct brain structures. (Kepecs & Mainen,2012).

Most decisions to act have to integrate subjective cognitive uncertainty and world affordances

Cognitive "affordance" sensing

- Does not require concepts such as uncertainty, memory, perception, reliability.

- It requires
  - Pursuing a cognitive goal (< sensitivity to a given informational need)
  - detecting the present availability of information or lack thereof while performing a task.
  - **Adjusting commands to task progress ("control sensitivity")**

Evaluative attitudes

No contrast between an object and a concept

No combinatorial ability

No deductive, inferential power

No embedding

But still structure:

- Predictive ability connected with reactive action schemas
- Associative network
- Graded sensitivity to affordances
- Graded control precedence

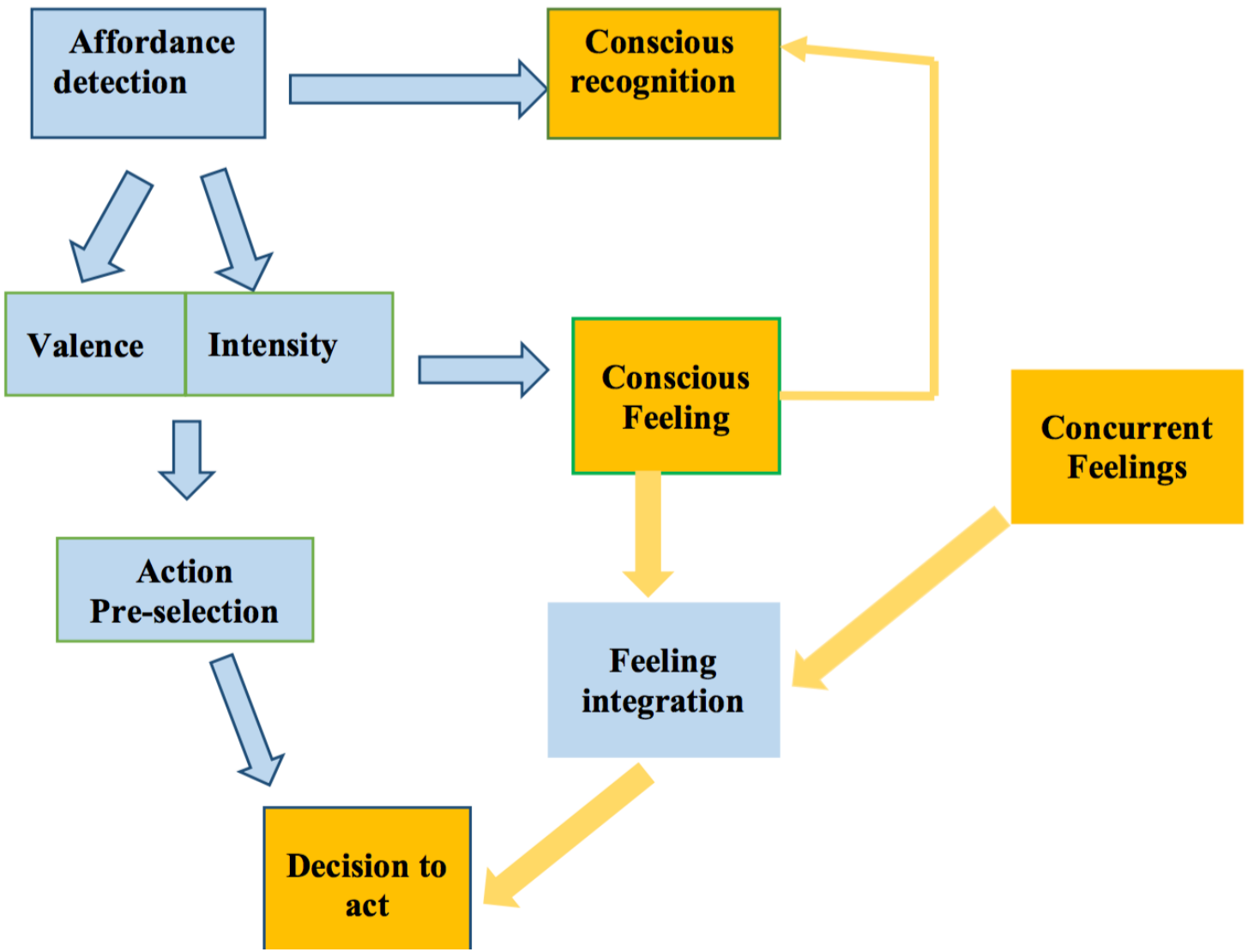
An affordance sensing is a **dynamic occurrent cognitive event**

Including

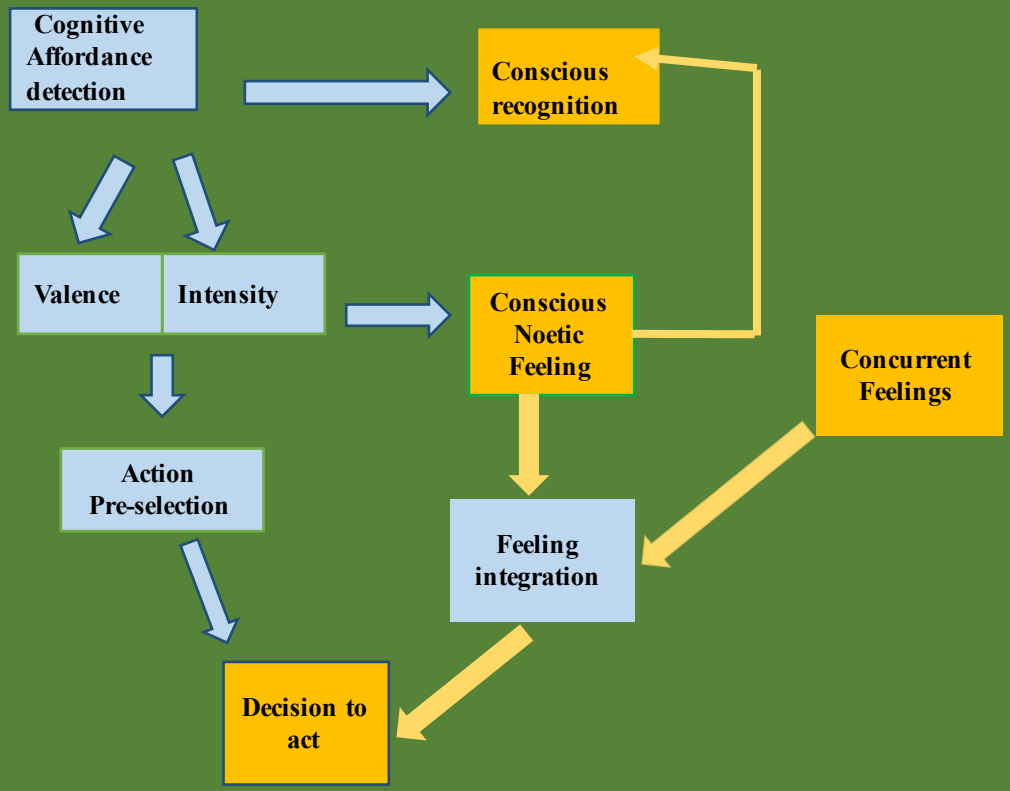
- Affordance detection (predictive cues) in present context of activity
- **Affordance recognition** (conscious sensory index)
- **Evaluation of valence and intensity (unconscious heuristics+conscious feelings)**
- **Total motivation** to act (others feelings involved)
- **Decision** to act

Nb: blue= nonconscious

Orange = conscious


Affordance detection
Conscious recognition
Valence
Intensity
Conscious Feeling
Concurrent Feelings
Action Pre-selection
Feeling integration
Decision to act

Cognitive affordance



The semantic structure of evaluative attitudes (affordance sensings)

- Affordance$_a$ [Place=here],[Time= Now/soon],
- [Valence$_a$],
- [Intensity$_a$ (on a scale 0 to 1)],
- [motivation of degree$_d$ to act according to action program$_a$].

→All the constituents are associatively related to perceptual cues in the affordance sensing

→ A subset may activate the full representation

Role of feelings in the semantic structure of affordance sensings.

Affordance-valence - intensity in this predictive/ evaluative structure, taken together, constitute a feeling , whether

- « affective » (social-affective)
- Agentive
- Proprioceptive

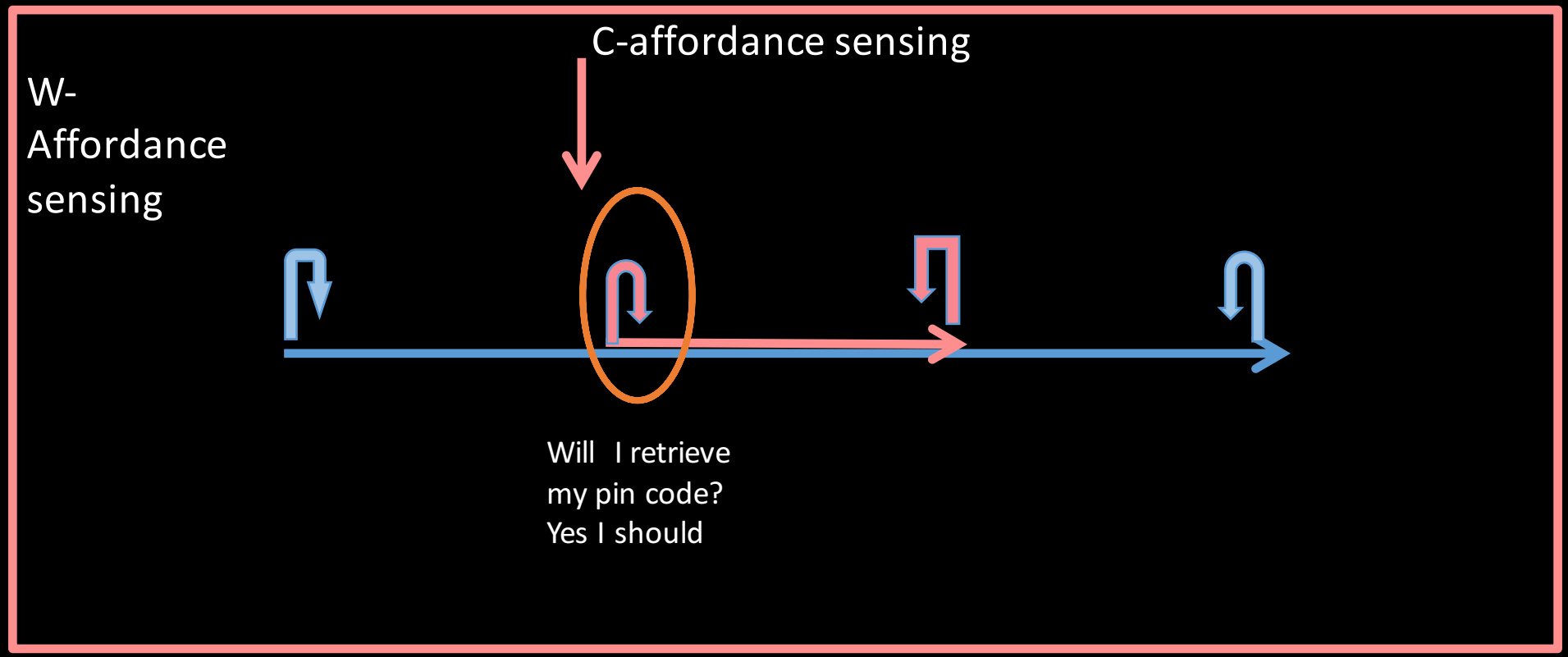
(for a defense: see Proust 2015)

Noetic feelings represent epistemic affordances

Examples:

- Affordance familiar/ rememberable, clear, [Time= present task],
- [Valence$_a$], positive
- [Intensity$_a$ (on a scale 0 to 1)],
- [motivation to act of degree$_d$ according to action program$_a$]. Identify! Remember! Accept!
- New cues can be added over time

Cognitive actions are **embedded** in world-directed actions



Informational source of noetic feelings?

Not primary thought content, but the dynamic signature of thought vehicle:

- Processing onset,
- intensity (increased coherence of cognitive activity over time)
- Latency to reach threshold (fluency)

predict together likely cognitive success of a given decision.

(Kiani & Shadlen, 2009,Fleming, 2014).

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In summary: noetic feelings

- Express a relation, not a state of affairs
- Indicate a subjectively relevant condition and motivate an action (« pushmi-pullyu », Millikan 1995)
- Are evaluative and graded

→Nonpropositional

→Do not conceptualize, but detect and categorize affordances

5. Conclusion: animal metacognition?

Evidence for non-human metacognition

- Offers a powerful argument in favor of the causal role of affordance-sensings as simulatenously receptive-executive non propositional representations.
- Affordance sensings are the common representational structure of all kinds of feelings.
- They qualify as a phylogenetic older form of evaluative representation.
- They provide a plausible semantic analysis of alarm calls in monkeys (see Proust, 2016)

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