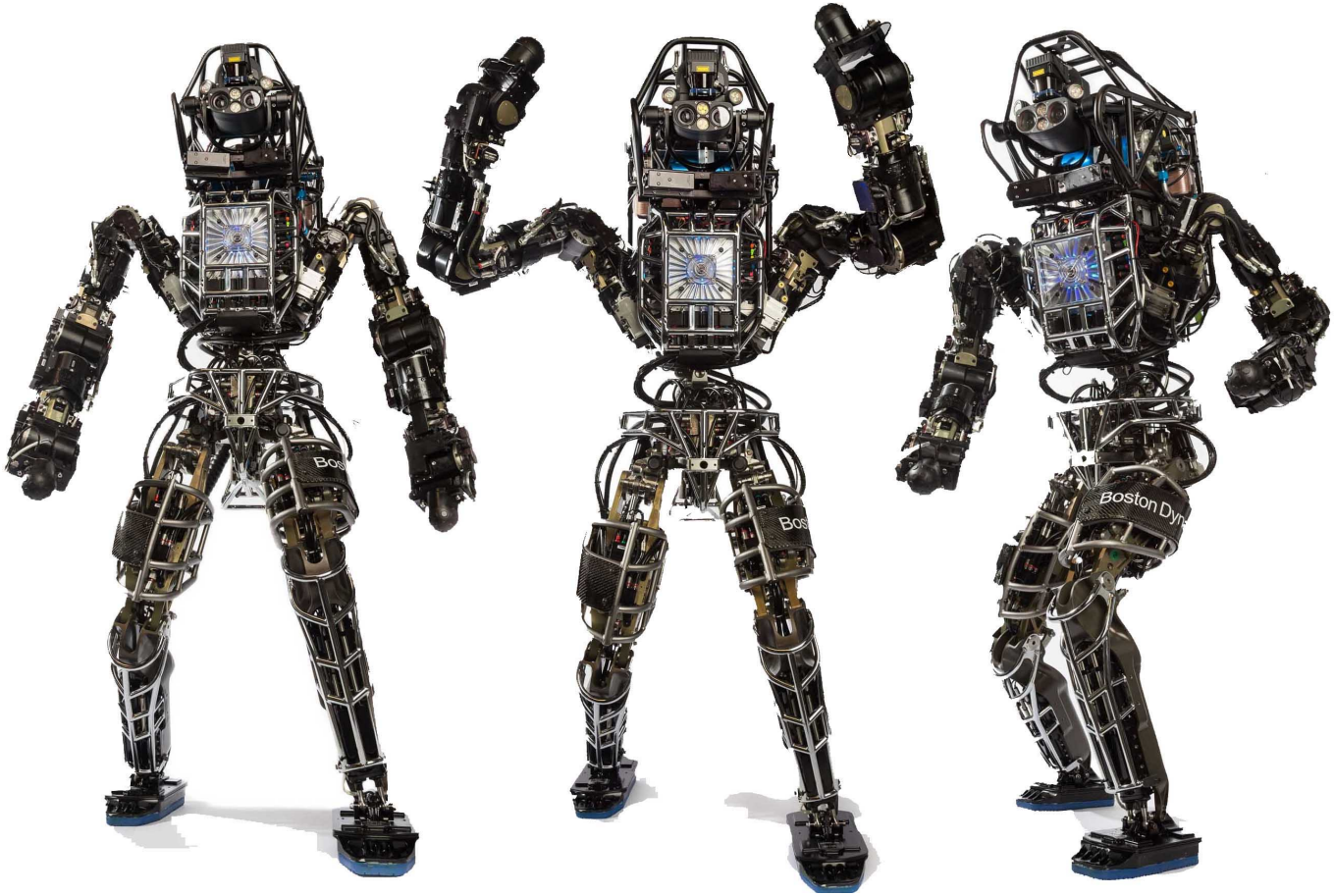
Introduction to Cognitive Science



Dr. Mark Miller

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Next: **Action**

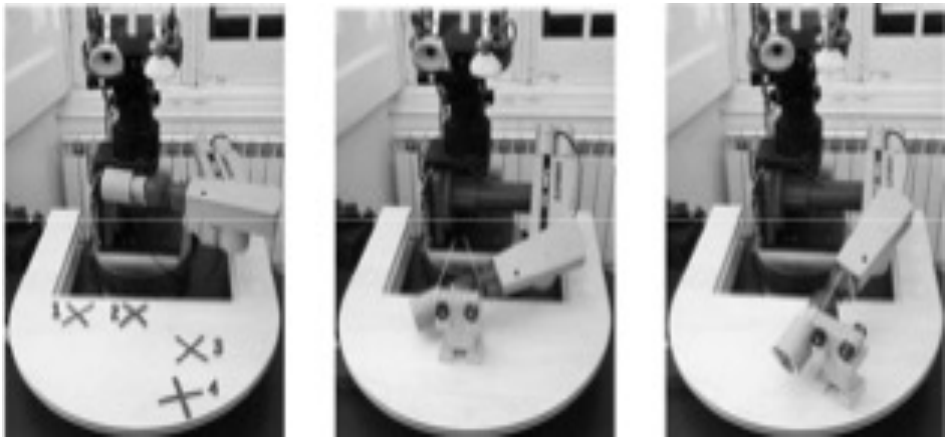
Next: **Action**

It is not just the gross form and bio-mechanics, that may be doing unexpected work, but also the **skilled use of the body in action.**

Key contribution of action concerns the power of what Lungarella and Sporns call the **active self-structuring of a data flow**

Lungarella, M., Sporns, O. (2005) Information self-structuring: key principle for learning and development. *Proceedings 2005 IEEE Intern. Conf. Development and Learning*, pp. 25-30.

A simple example: **BABYBOT** (Metta and Fitzpatrick) learns about object boundaries by poking and shoving.



Metta, G. and Fitzpatrick, P. (2003). Early integration of vision and manipulation. *Adaptive Behavior*, 11(2):109—128.

So BABYBOT's own motor action has now induced an **informative sensorimotor correlation**: the sudden spread of motion **identifies the boundaries of an object.**



This isn't just a trick for babies…

We are rampant **self-structured of our own informational flows**.

In higher cognition we constantly **sketch, scribble, gesture and talk to ourselves**, creating structured flows of visual and auditory stimulation that can enhance and guide our own cognitive activity

Experimental work by Goldin-Meadow suggest that **spontaneous gesture is doing important cognitive work**, and is not merely a side-effect or aid to communication.

Some more clues…

- We do it when we talk on the phone
- We do it when we talk to ourselves
- We do it in the dark, no one can see
- Gesturing increases when genuinely reasoning about a problem, rather than just describing a known solution.

Interestingly,

Speakers blind from birth, who have never spoken to a visible listener, and never seen others moving their hands as they speak, also gesture when they speak

Moreover, they do so even when they are speaking to others they know to be blind

More empirical research showing that if you suppress gestures you suppress cognitive task

A possible model:

In gesture, as when we write to talk, we materialize our own thoughts, we bring something concrete into being

That thing can then systematically reflect, but also alter and effect, our own ongoing thinking and reasoning

What Dennet (1991) calls the power of **cognitive self-stimulation**

Speech, gesture and neural activity continuously inform and are informed by each other, together constituting a single integrated cognitive system" (Iversen & Thelen 1999)

"A dynamic mutuality [involving words, gesture and neural activity] such that activity in any one component can potentially entrain activity in any other" (2001 p.37)

"the gesture, the actual motion of the gesture itself, is a dimension of thinking" (Mc Neil 2005 p.98)


MASTER MIND
ABACUS

A general picture:

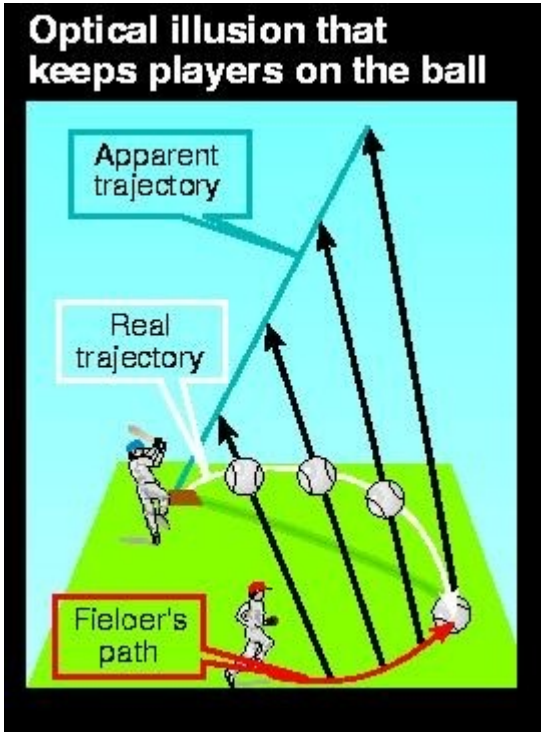
At many levels, **self-generated motor activity** acts as a "**complement** to neural information-processing", creating new, whole, **highly complex, systems** in which

"'information structuring' by motor activity and 'information processing' by the neural system are continuously linked to each other through sensorimotor loops" Lungarella and Sporns (2005).


ANY
QUESTIONS?

Next: The Role of **Sensing**…

Active embodied agents can also use **sensing** in ways that are rather different to the way imagined in the classical bubble of reason/ Sense-Think-Act cycle picture



Consider running to catch a fly ball in baseball…

Run so you cancel the **vertical acceleration of the ball's optical projection** – see the neat VR experiments reported in Fink, Foo, and Warren (2009)

McBeath, M. K., Shaffer, D. M., & Kaiser, M. K. (1995). How baseball outfielders determine where to run to catch fly balls. *Science*, 268, 569–573.

Fink, P. W., Foo, P. S., & Warren, W. H. (2009). Catching fly balls in virtual reality: A critical test of the outfielder problem. *Journal of Vision*, 9(13):14, 1–8



Similar for how dogs catch frisbees (Shaffer et al (2004))

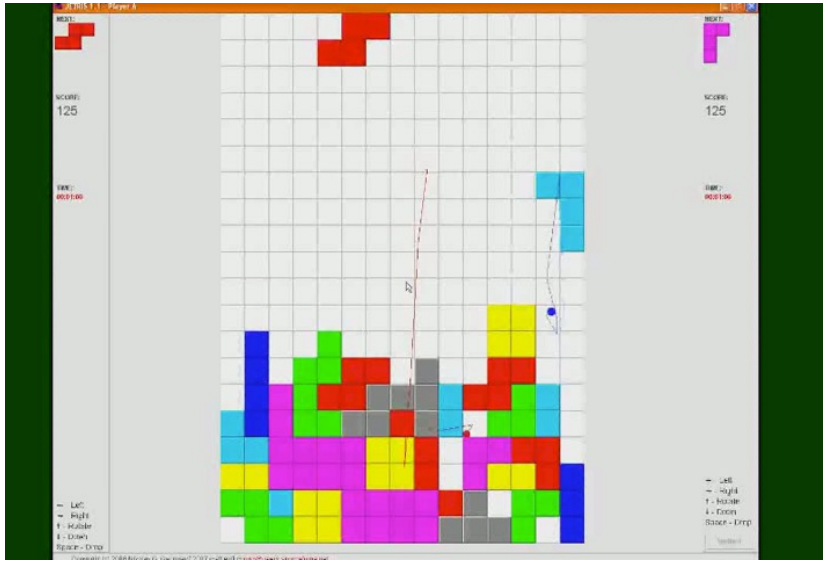
Sensing is not used, in this case, to get sufficient information inside the brain to allow it to solve the whole problem in one go

(Not: sense-**ponder**-run to catch ball)

Instead, **sensing is geared to acting, and acting is geared to sensing, in a rolling cycle**

You run so that the **visual input stays within certain bounds**, and that solves the problem..

Frequent saccades enable us to circumvent the need to build enduring and detailed models of our visual surroundings.



"We can use the world as its own best model and visit and rev

See Kirsh and Maglio's (1994)

The Point:

Sensing need not always be used **re-constructively** i.e. to prime a rich world-model that enables the agent to reason over the model **instead of** the world.

Instead, active systems can use sensing in more direct ways, as the fly-ball case suggests.

A lot of expert sports skill probably depends on these kinds of uses of sensing.

Second Moral of the Embodied Mind: **Cognition leaks into whole action-perception loops.**

The presence of a self-controlled, acting, sensing body allows an agent to **sculpt her own sensory input streams** in ways that promote learning, reasoning, and efficient problem-solving.

The engine of some forms of cognizing then isn't the naked brain - but rather whole complex system including brain and the sensing-acting-moving body.


ANY
QUESTIONS?

Spreading into the **environment**…

The Bluefin Tuna Puzzle:



Spreading into the **environment**…

The Bluefin Tuna Puzzle:

The aquatic performance of the Bluefin Tuna far exceeds its basic physical capacities.

e.g. they should not be Abel to go as fast, turn as sharp, or excel with such force…

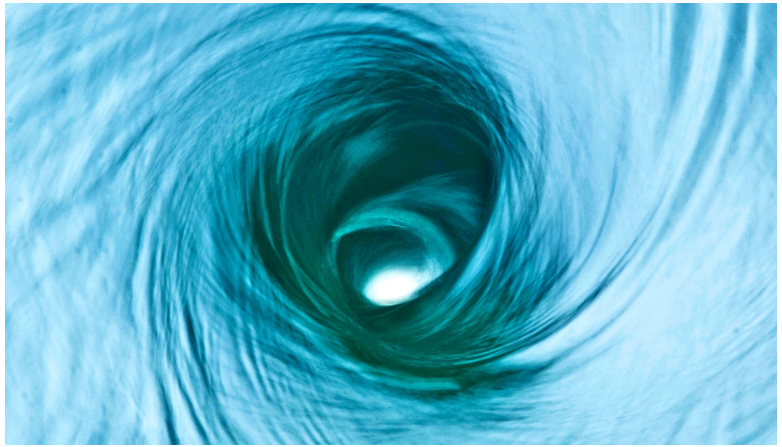
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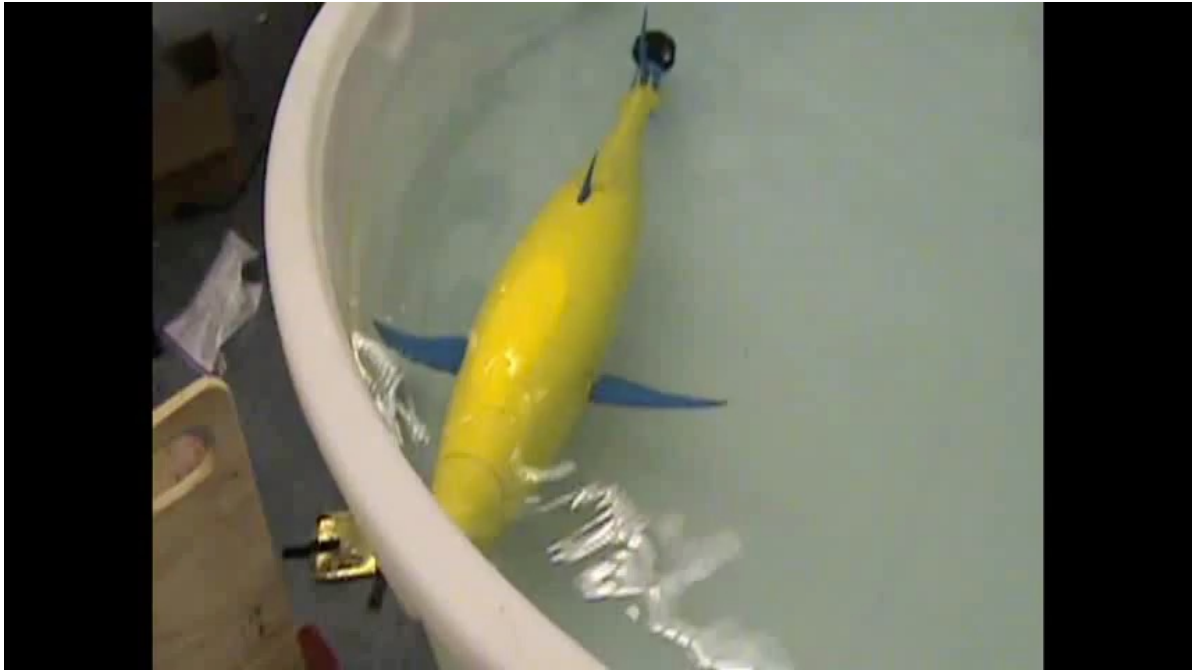


How does this work:

Tuna makes the most of the world around them, using naturally occurring eddies and cortices (e.g. where water hits a rock)

They use their own tail-flaps to create local vortices and pressure gradients that they then exploit for power.





Now we're creeping up on **higher cognition**…

We also **structure our worlds** to simplify our thinking.

Consider now our own artifact-enhanced cognitive processing

Classic Example: **Long Multiplication**

Most of us can do simple multiplications by learning a few rote patterns e.g

7 x 7 is 49

But what about

7466796 X 74965

Familiar but potent trick is to **combine** simple neural pattern completion strategies and the **use and manipulation of external symbols and media** e.g. pen and paper – reducing the complex problem to a set of simpler pattern-completing operations.

e.g. physically shuffling the **scrabble** tiles to prompt word recall.



Famous exchange between **Richard Feynman** (the Nobel laureate physicist) and the historian **Charles Weiner**

> " Weiner once remarked casually that [a batch of notes and sketches] represented "a record of [Feynman's] day-to-day work," and Feynman reacted sharply.
>
> "I actually did the work on the paper," he said.
>
> "Well," Weiner said, "the work was done in your head, but the record of it is still here."
>
> "No, it's not a *record*, not really. It's *working*. You have to work on paper and this is the paper. Okay?" "

As quoted in *Genius* (Gleick's biography of Feynman)

Stronger Claim: The Embodied/Extended Mind

Its not that all the real thinking happens inside the head and loops out into the body, and external media is just for offloading or storage

But all of these things **become part of thinking**

Questions to ponder:

Can high-level reason do without **richly reconstructive inner world-models**?

What **role** (if any) does embodiment play in cases of higher-level reasoning?

In what ways might the presence of **spoken language** and other cognitive technologies transform the tasks involved in higher-level reasoning?


ANY
QUESTIONS?

MORE!



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frontiers in Human Neuroscience

HYPOTHESIS AND THEORY
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The embodied brain: towards a radical embodied cognitive neuroscience

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In this programmatic paper we explain why a radical embodied cognitive neuroscience is needed. We argue for such a claim based on problems that have arisen in cognitive neuroscience for the project of localizing function to specific brain structures. The problems come from research concerned with functional and structural connectivity that strongly suggests that the function a brain region serves is dynamic, and changes over time. We argue that in order to determine the function of a specific brain area, neuroscientists need to zoom out and look at the larger organism-environment system. We therefore argue that instead of looking to cognitive psychology for an analysis of psychological functions, cognitive neuroscience should look to an ecological dynamical psychology. A second aim of our paper is to develop an account of embodied cognition based on the inseparability of cognitive and emotional processing in the brain. We argue that emotions are best understood in terms of action readiness (Frijda, 1986, 2007) in the context of the organism's ongoing skillful engagement with the environment (Rietveld, 2008; Bruineberg and Rietveld, 2014; Kiverstein and Rietveld, 2015, forthcoming). States of action readiness involve the whole living body of the organism, and are elicited by possibilities for action in the environment that matter to the organism. Since emotion and cognition are inseparable processes in the brain it follows that what is true of emotion is also true of cognition. Cognitive processes are likewise processes taking place in the whole living body of an organism as it engages with relevant possibilities for action.

Keywords: emotion cognition interactions, psychological constructionism, salience network, embodied cognition, affordances, dynamical systems theory

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Introduction

Radical embodied cognitive science is a relatively new branch of cognitive science that looks to ecological psychology and dynamical systems theory to understand the contribution of bodily capacities to cognitive processes (Chemero, 2009; Barrett, 2011). It is "radical" in claiming that cognitive scientists need new conceptual tools if they are to understand the ways in which cognition depends on the body in its interaction with the environment. The classical conception of the human mind as working according to the same principles as a digital computer encourages us to think of the body and the environment as providing at best inputs to, and receiving outputs from cognitive processes (Rupert, 2009). Embodied approaches to cognitive science by contrast stress the many and varied ways in which an animal's environmental niche offers resources for



Radical Embodied Cognitive Science:

Neural dynamics can only be studied while taking into account the larger brain-body-environment dynamics (Chemero, 2009).

Radical embodied cognitive science looks to **ecological psychology** and **dynamical systems theory** (Chemero 2009; Barrett 2011).

We propose that the problem faced by cognitive neuroscience to attribute function to specific brain structure can only be solved by zooming out and considering the **larger organism-environment system**.





The Cognitive-Emotional Brain

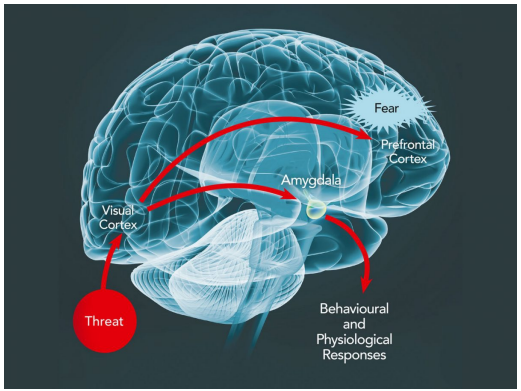
Typical interaction between cognitive psychologist and neuroscientist:

Folk psychology makes distinctions between episodes of anger, disgust, fear, happiness, sadness, etc…



Then we ask: how do these folk psychological emotion categories map onto processes in the brain?





Emotion:

Automatic, not necessarily human, sub-cortical, evolutionarily older and more basic; physiological and neural arousal, action tendencies.

Affective neuroscientists have posited a set of biologically basic emotions such as rage, fear, lust, care, and grief that can be localized to specific and dedicated networks in the human brain (Panksepp 1998; 2012).

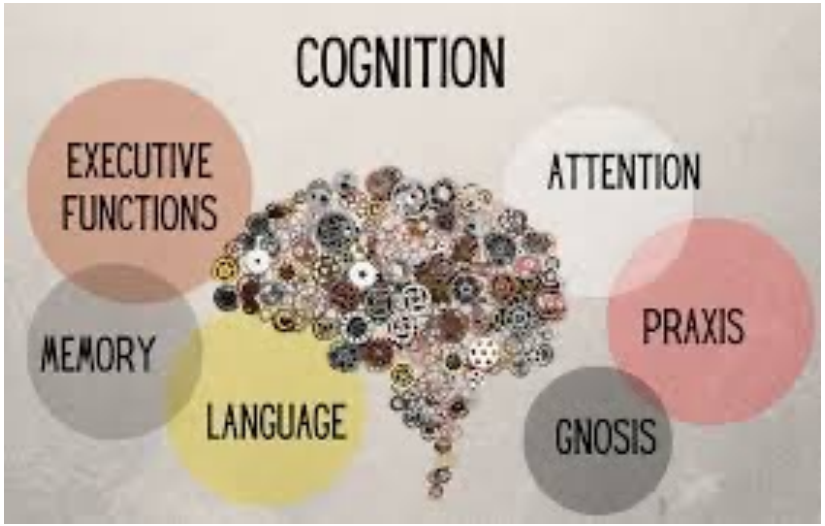


Cognition:

Sophisticated, controllable, human, cortical; Evaluation, decision, memory, attention, perception.

Cognitive processes (such as learning and memory, reasoning and planning) are often associated with the phylogenetically newer and more highly evolved cerebral cortex

The primate neocortex for instance shows a fivefold difference in volume when compared to that found in insectivores (Barton & Harvey 2000). This growth is thought by many to be accompanied by an evolution of higher-cognitive functions.

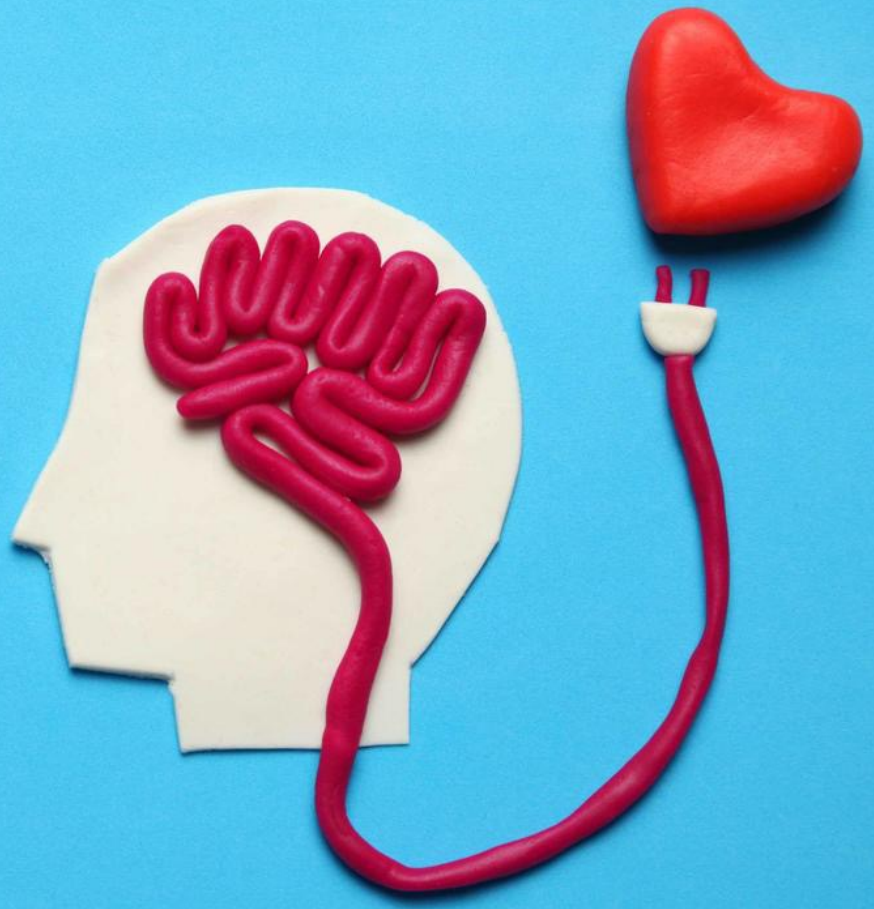


How do they relate?

From the late 19th century until recently neuroscientists approached the study of the brain from the perspective of "**functional localization**".

Brain is divided into **cognitive "higher" regions** (neocortex) and **emotional "lower" subcortical regions**.

"the higher nervous arrangements evolved out of the lower keep down those lower, **just as a government evolved out of a nation controls as well as directs that nation**." (John Hughlings-Jackson, 1884).

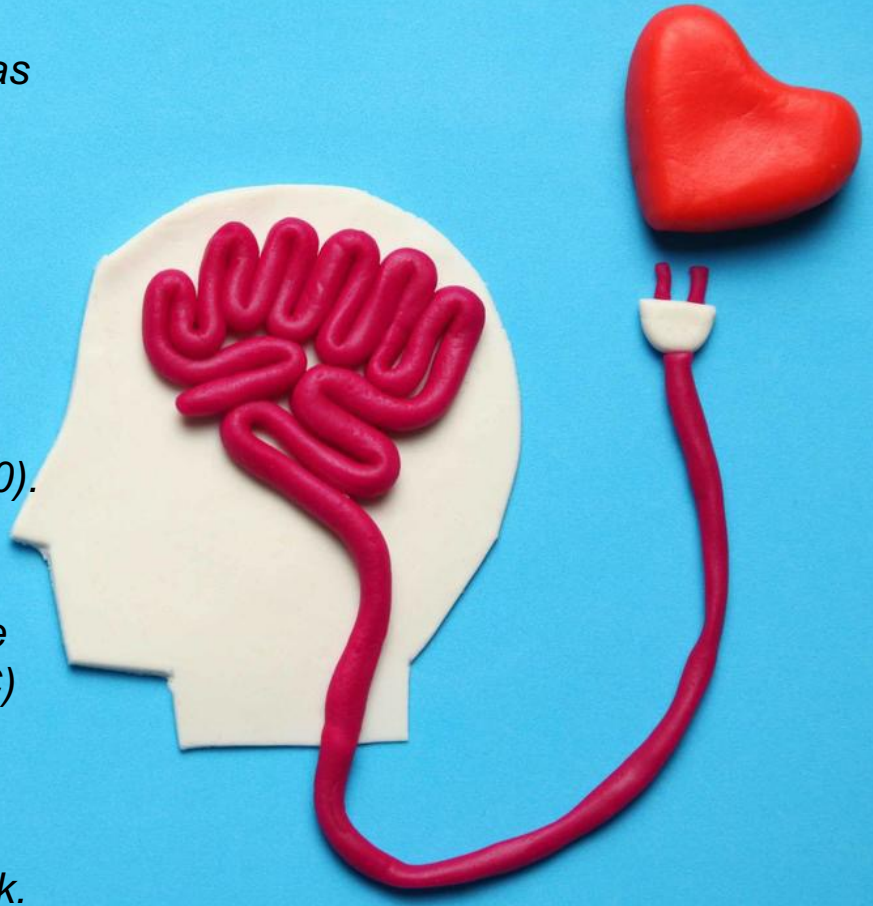


How do they relate?

The neocortex in primates has been described as the “crowning achievement of evolution and the biological substrate of the human mental prowess.” (Rakic 2009, quoted by Barton 2012: 2098).

The primate neocortex for instance shows a fivefold difference in volume when compared to that found in insectivores (Barton & Harvey 2000).

This growth is thought by many to be accompanied by an evolution of higher-cognitive functions. Systems in the prefrontal cortex (PFC) for instance make use of information that has been processed by other parts of the brain to ensure that we, in contrast to our animal ancestors, keep our emotional impulses in check.



The triune brain

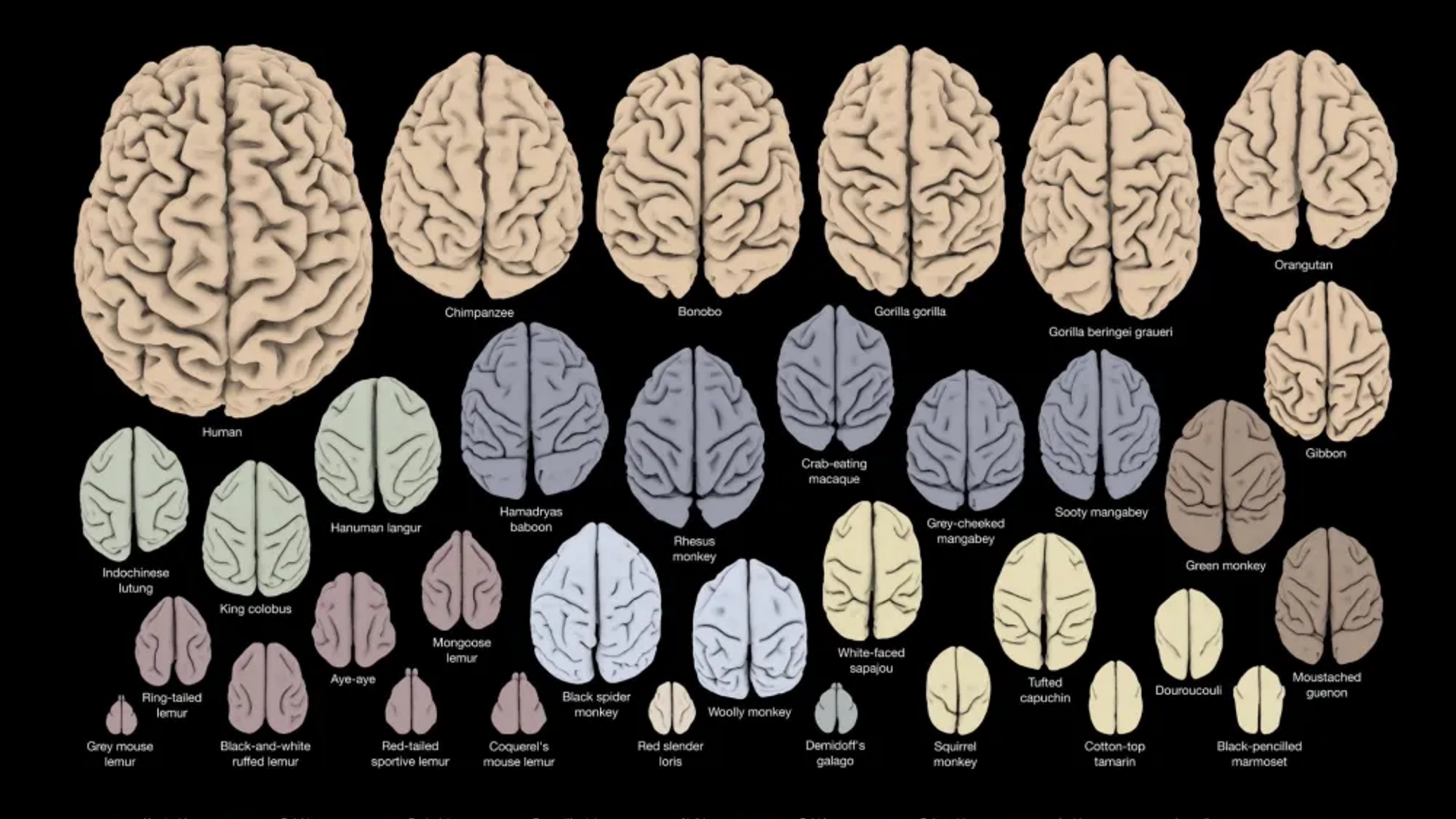
'Mammal'
(paleopallium)
Emotion, seek pleasure, avoid pain

'Reptile'
(archipallium)
Survival, fear



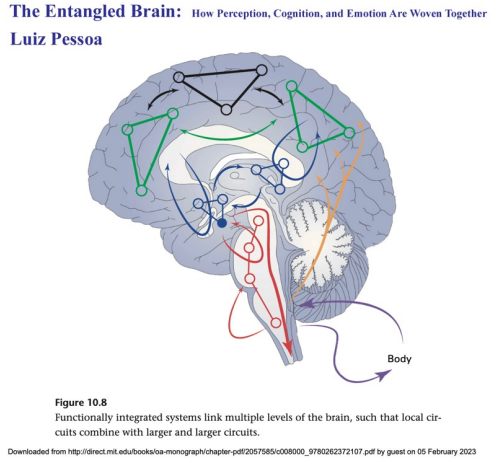
'Rational'
(neopallium)
Logic and thinking

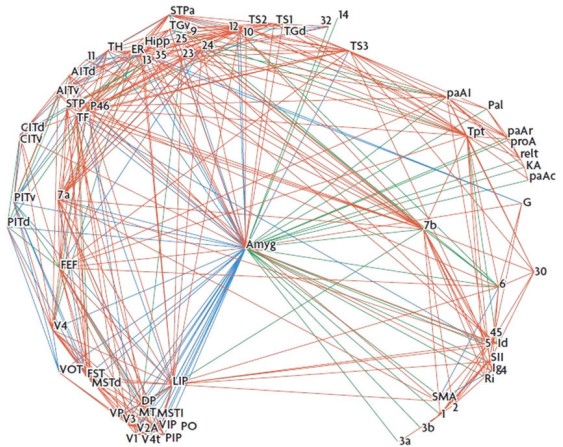
http://en.wikipedia.org/wiki/Triune_brain


Human
Chimpanzee
Bonobo
Gorilla gorilla
Gorilla beringei graueri
Orangutan
Gibbon
Hamadryas baboon
Rhesus monkey
Crab-eating macaque
Grey-cheeked mangabey
Sooty mangabey
Green monkey
Hanuman langur
Indochinese lutung
King colobus
Mongoose lemur
Aye-aye
Ring-tailed lemur
Grey mouse lemur
Black-and-white ruffed lemur
Red-tailed sportive lemur
Coquerel's mouse lemur
Black spider monkey
Red slender loris
Woolly monkey
Demidoff's galago
White-faced sapajou
Squirrel monkey
Tufted capuchin
Cotton-top tamarin
Douroucouli
Black-pencilled marmoset
Moustached guenon

Alternative Brain Evolution Story:

- Cortex and sub-cortex changed in a **coordinated fashion** (Barton & Harvey 2000).
- Evidence for a **threefold co-evolution** of the diencephalon, cerebellum and the neocortex.
- The **cerebellum** (associated with learning motor skills) is larger in primates compared with other mammals.
- Subregions of the **amygdala** are substantially more developed in monkeys as compared with rats (Chareyon et al 2011) - this increase in size in the amygdala is likely to be **linked to the degree of connectivity with other brain structures** (Pessoa 2014).





Joseph Parvizi (2009) offers an important critique of this "**corticocentric myopia**". In his words "higher functions of the brain are made possible by a **reciprocal interconnection between cortical and subcortical structures** rather than being localized only in the upper tip of the vertical neuroaxis.

This means that there are complex relations of negative and positive feedback that characterize the communication between sub-cortex and cortex.

Parvizi suggests that higher brain functions (such as **executive control functions**) happen in "**the loops operating between** the cortical areas and 'lower' subcortical structures such as the basal ganglia; the basal forebrain; the thalamus; the cerebellum; and the brainstem dopaminergic and noradrenergic systems.

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Trends in Cognitive Sciences
CellPress
Volume 13, Issue 8, August 2009, Pages 354-359

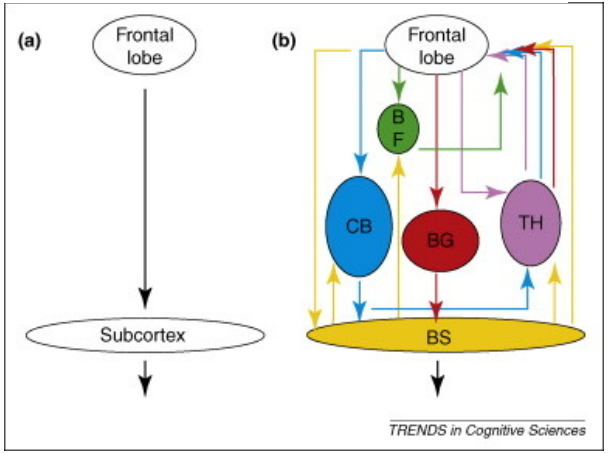
Opinion

Corticocentric myopia: old bias in new cognitive sciences

Josef Parvizi

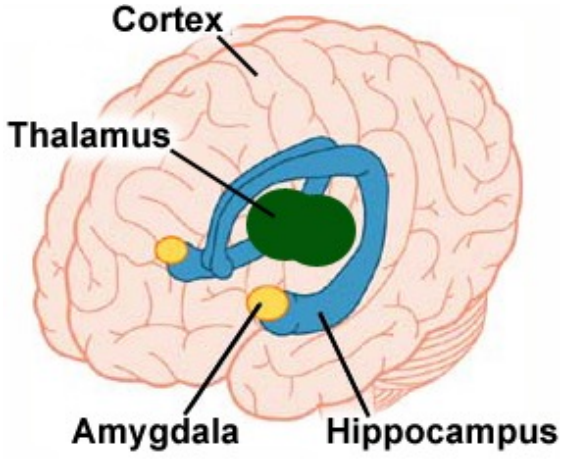
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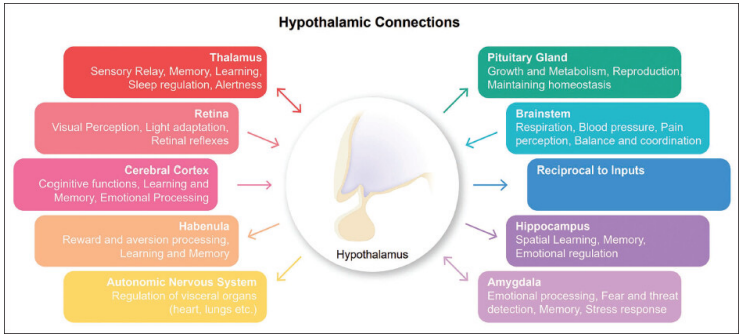
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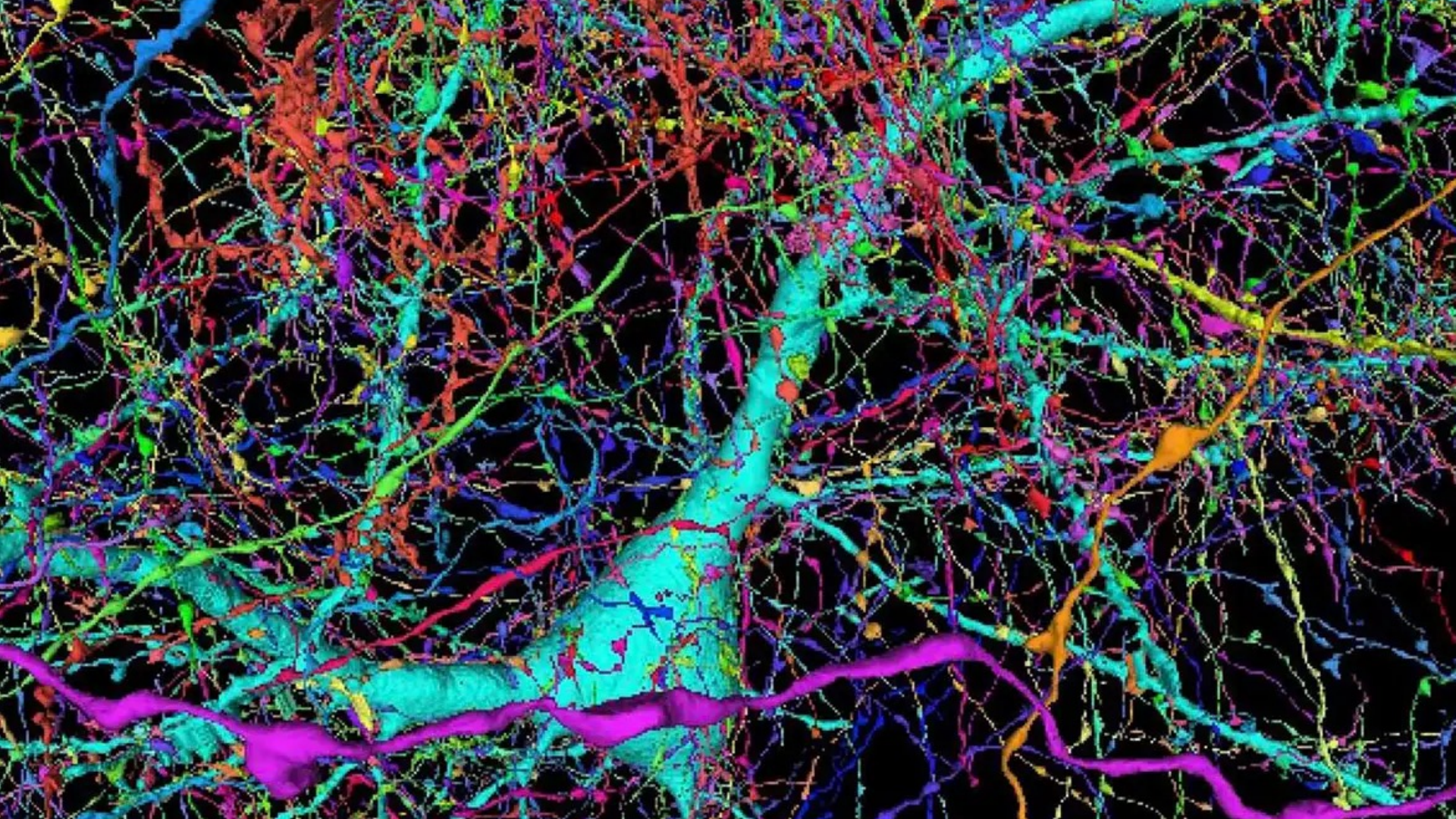


Consider the **hypothalamus**:

- The hypothalamus is commonly associated with the **coordination of homeostatic mechanisms**, e.g. hormonal and behavioral circadian rhythms and neuroendocrine processes.
- However, it is also bidirectionally connected to the cerebral cortex by at least four pathways that run via the **basal forebrain** and **amygdala**; the **brainstem** and the **thalamus** (Risold et al 1997);
- In primates the hypothalamus **projects to all regions** (orbital, medial and lateral) **of the prefrontal cortex** (Barbas & Rempel-Clower 1998);
- The hypothalamus functions as a so-called "**connectivity hub**" that is optimally placed because of its extensive connections to have a near global effect on brain function (Pessoa 2013).
- This **bidirectional and reciprocal connectivity** allows for **rapid coordination and synchronization** of activity between **"higher" and "lower" brain systems**, allowing cognitive and affective processes to be mobilized together, allowing the animal to behave flexibly, and in ways that are adapted to the particularities of a context of activity.



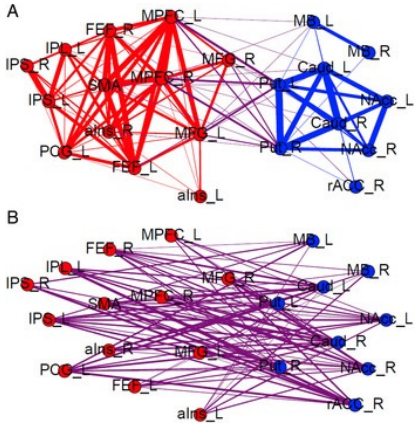


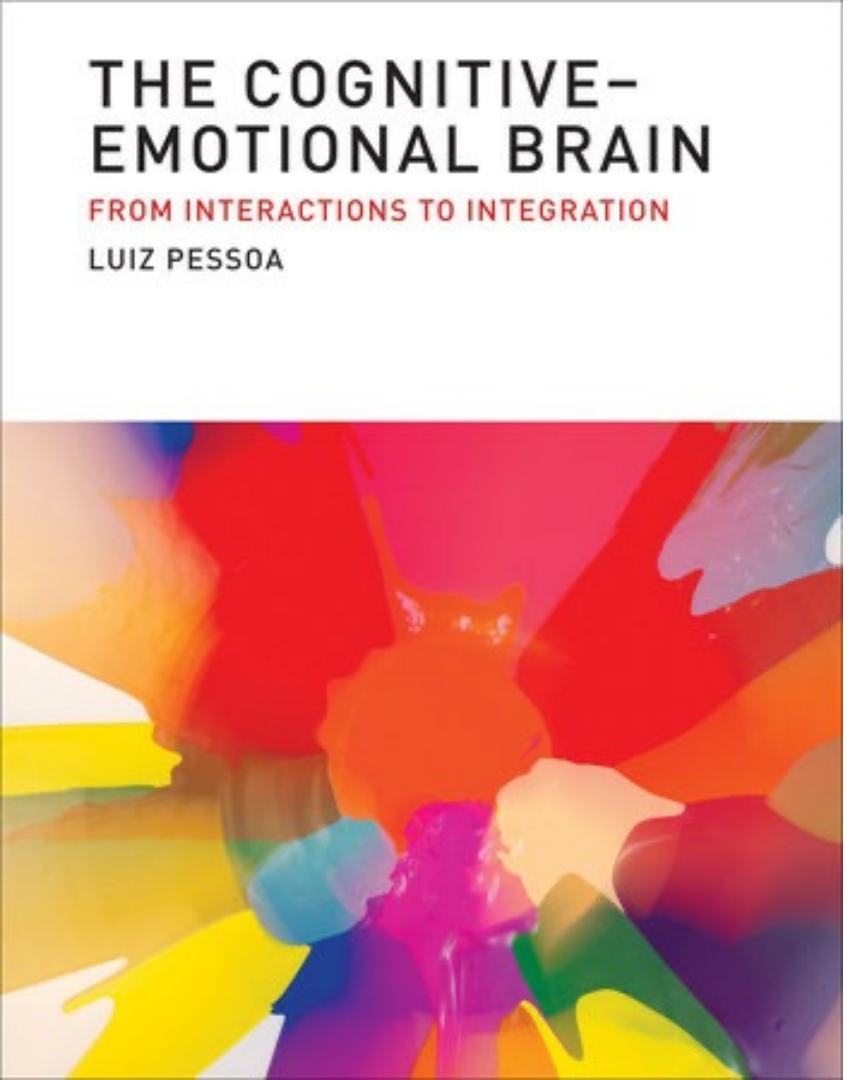


Pluripotency: one and the same region (e.g. Broca's area) can be involved in the performance of multiple functions (e.g. language processing, movement preparation, imitation and imagery related tasks (see Anderson 2010)

Degeneracy: different neural structures can perform one and the same function (Edelman & Gally 2001; Friston & Price 2003; Figdor 2010).

Taken together these findings suggest a ***many-to-many*** mapping of structure to function at the level of brain regions.





The neural computations responsible for any behaviour "**should not be thought of as implemented by an individual area**, but rather by the interaction of multiple areas" (Pesoa, 2008: 154).

During complex behaviour neural connector hubs recruit various neural clusters (**both emotional and cognitive**) into transient large scale functional networks.

"There are no truly separate systems for emotion and cognition because **complex cognitive-emotional behaviour emerges from the rich, dynamic interactions between brain networks**" (Pessoa, 2008).





“Mr. Smart slams on the brakes when noticing the proximity of the car in front. Anger arises initially from frustration, as Mr. Smart wants to keep driving fast, but also from a sense of violated entitlement: he is in the left lane and should not have to slow down. Fear may also be triggered by the close call, eliciting further anger because of an intermediate evaluation of unmanly helplessness. These emotions arise rapidly, but they are paralleled by a co-emerging sense of the other driver as intentionally obstructive (and therefore blameworthy). Mr. Smart’s highly focused visual attention, a derivative of anger, takes in the red color of the car ahead, as well as the expensive-looking design, and his anger is amplified by his sense of the unfairness of this show-off blocking his path (based on an implicit memory of some long-forgotten or fantasized rival). A stabilizing angry-anxious state, coupled with ruminative plans for vengeance (perhaps a blast of the horn), anchors attention to the head of the man in front. This lasts for a minute or two while Mr. Smart fashions and modifies plans to pass on the right. However, when the man peers over his shoulder, Mr. Smart evaluates this act as a taunt, generating shame and anger in an elaborated appraisal of humiliation, and calling for extreme action to save his self-image from further subjugation” (Lewis, 2005: 175).

A change in **emotional state is triggered** whenever orderly behavior “is interrupted by a perturbation, resulting in a rapid loss of orderliness and an increase in sensitivity to the environment” (Lewis, 2005: 174).

Once order has been disrupted, sub-cortical and cortical neural systems enter into a **series of recursive feed-back loops**, activity in the one system amplifying activity in the other (Lewis, 2005: 176).

- Example: positive feed-back loop between **bodily arousal** (realized in sub-cortical, limbic systems), and **attention and recall** (involving regions in the neocortex)
- The angry-arousal **focuses Smart's attentional resources onto the dangerous and transgressive elements** in the environment (driver of the red sports car). Increased attentional focus highlights the expensiveness of the automobile, which in turn triggers feelings of unfairness, which increase Smart's feelings of anger.
- Simultaneously, this **angry arousal anchors his recall processes to similar past situations**, and memories of past transgressors, which amplifies Smart's feeling of anger. Smart's bodily arousal motivates and directs his attentional and recall processes. These cognitive processes in turn intensify and prolong his state of anger arousal.

When the somatic and cognitive processes become appropriately coupled (anger in the form of bodily arousal directing attention and recall, attention and recall sustaining/amplifying bodily arousal) the brain systems supporting these psychological processes begin to **settle into stable patterns of activity** (Lewis, 2005).

The “lower” neural processes that track bodily arousal, and the “higher” neural processes associated with attention and memory sustain each other, and **generate an enduring emotional-cognitive state**


ANY
QUESTIONS?



The **Embodied** Cognitive-Emotional Brain

Thanks!



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