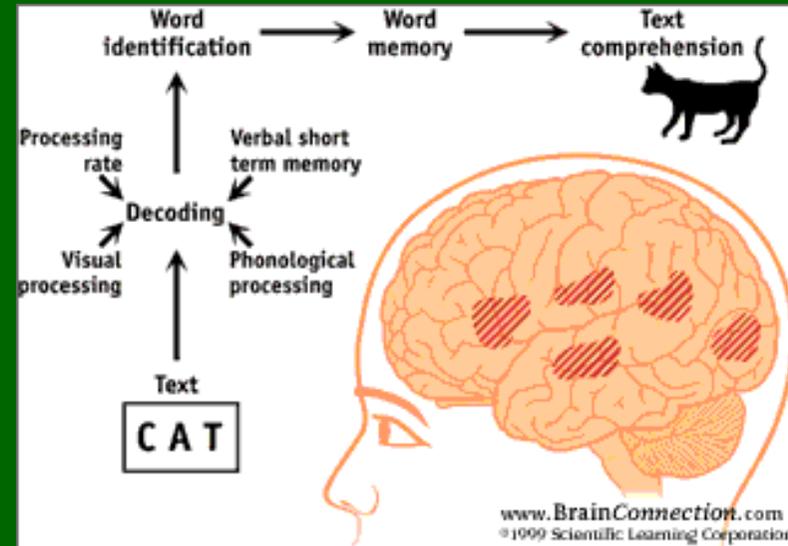


Selected topics in cognitive neuroscience and biomodeling

L14: Intelligence, Will, Decisions



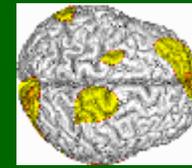
Włodzisław Duch

Neurocognitive Laboratory & Dept. of Informatics

Nicolaus Copernicus University, Poland

[Google: Wlodek Duch](#)

What it will be about



1. Connectomes and intelligence.
2. Reading brain states and biomarkers of mental disorders.
3. Dynamics of brain states.
4. Personal identity.
5. Will and decision making.
6. Summary.

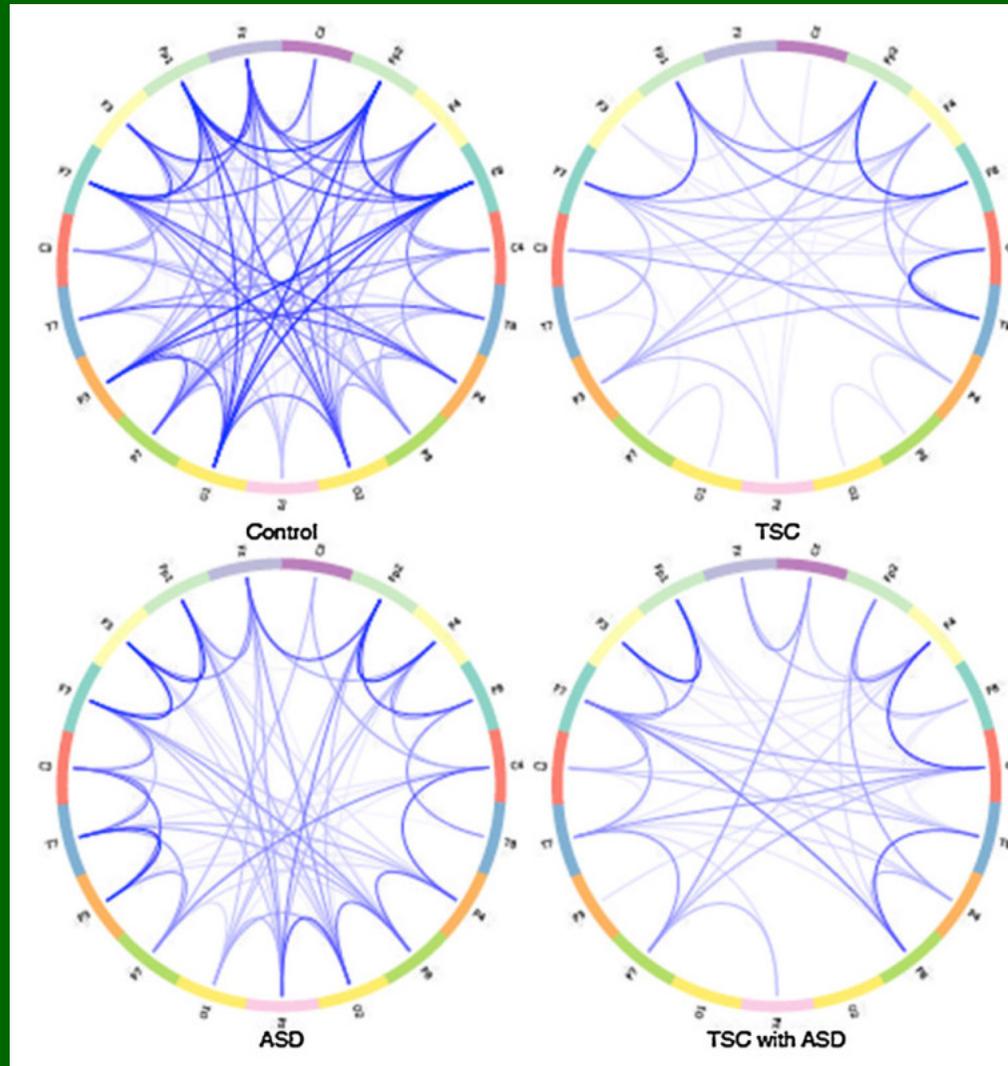


ASD: pathological connections

Comparison of connections for patients with ASD (autism spectrum), TSC (Tuberous Sclerosis), and ASD+TSC.

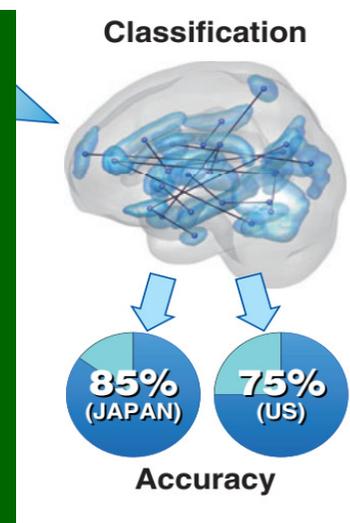
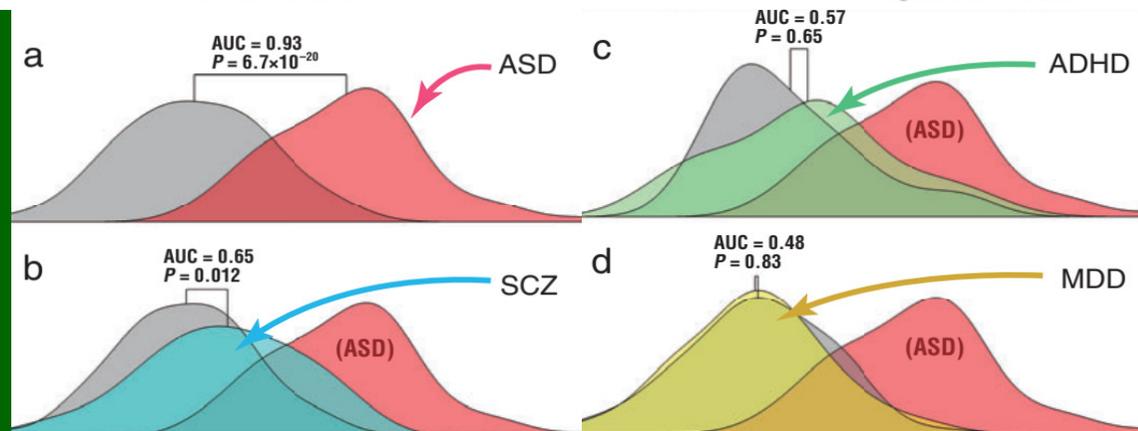
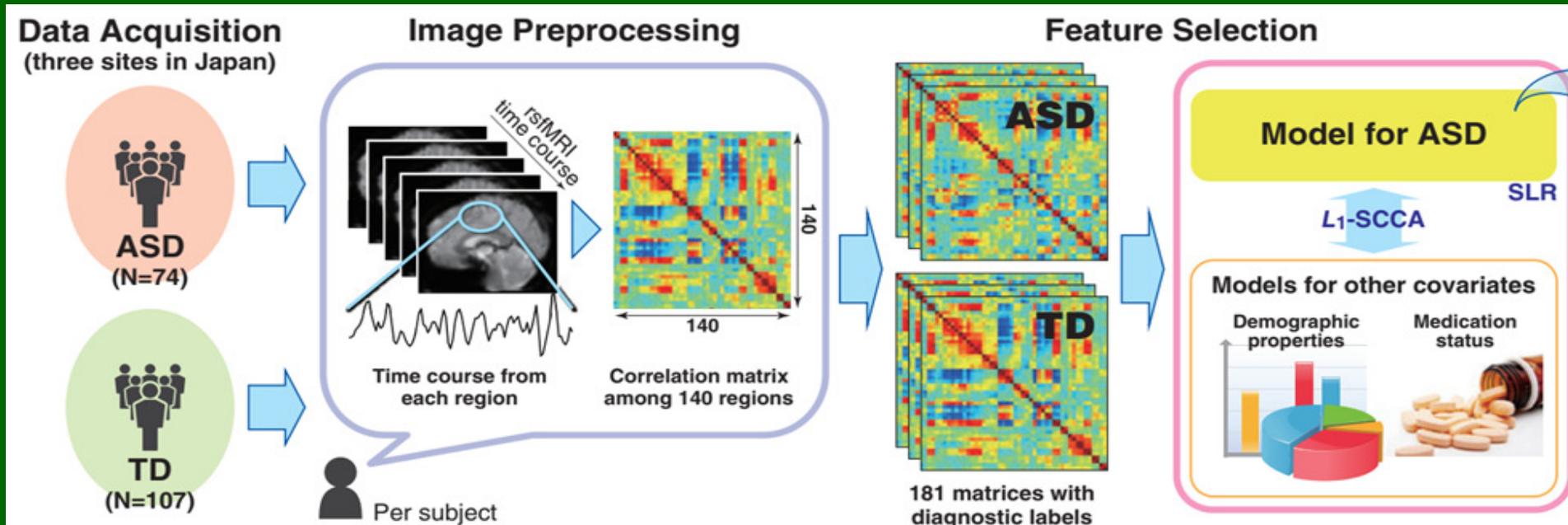
Coherence between electrodes. Weak or missing connections between distant regions prevent ASD/TSC patients from solving more demanding cognitive tasks.

Network analysis becomes very useful for diagnosis of changes due to the disease and learning; **correct your networks!**



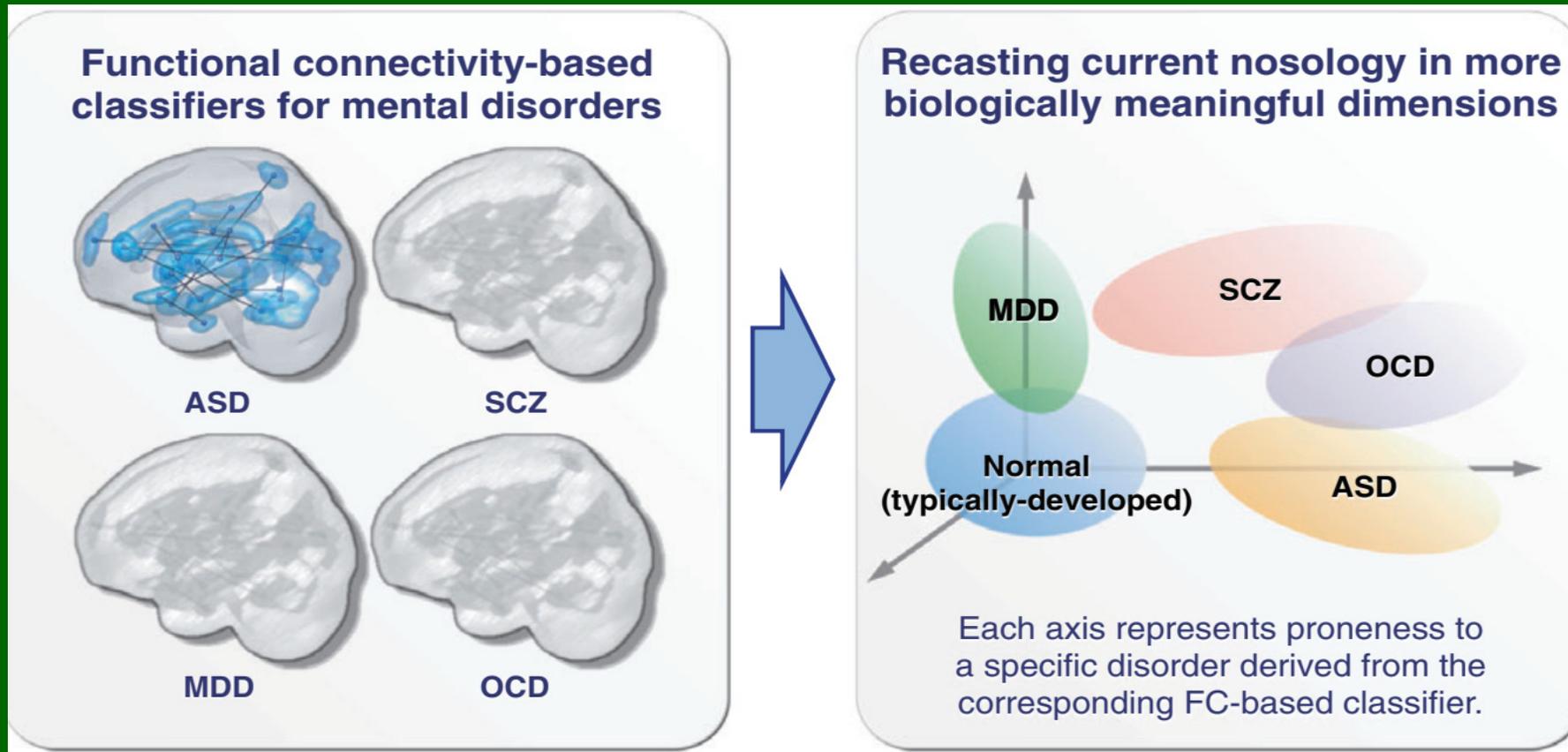
J.F. Glazebrook, R. Wallace, Pathologies in functional connectivity, feedback control and robustness. *Cogn Process* (2015) 16:1–16

Biomarkers from neuroimaging



N. Yahata et al, *Psychiatry and Clinical Neurosciences* 2017: 71

Biomarkers of mental disorders



MDD, deep depression, SCZ, schizophrenia, OCD, obsessive-compulsive disorder, ASD autism spectrum disorder. fMRI biomarkers allow for objective diagnosis.

N. Yahata et al, *Psychiatry & Clinical Neurosciences* 2017; **71**: 215–237

Brain modules and cognitive processes

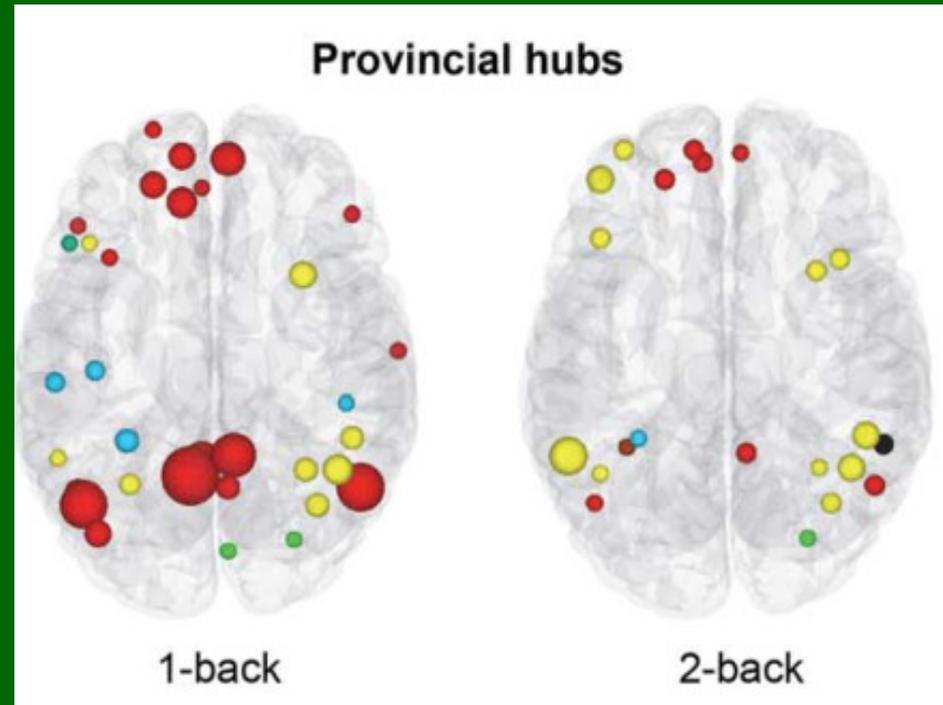
Simple and more difficult tasks, requiring the whole-brain network reorganization.

Left: 1-back local hubs

Right: 2-back local hubs

Average over 35 *participants*.

Dynamical change of the landscape of attractors, depending on the cognitive load. Less local (especially in DMN), more global binding (especially in PFC).



Finc K, Bonna K. et al. (2017) Transition of the functional brain network related to increasing cognitive demands. *Human Brain Mapping* 38(7), 3659–3674

Difficult cognitive processes

If the problem is hard recruit more brain regions to solve it! Functional synchronization unifies them.

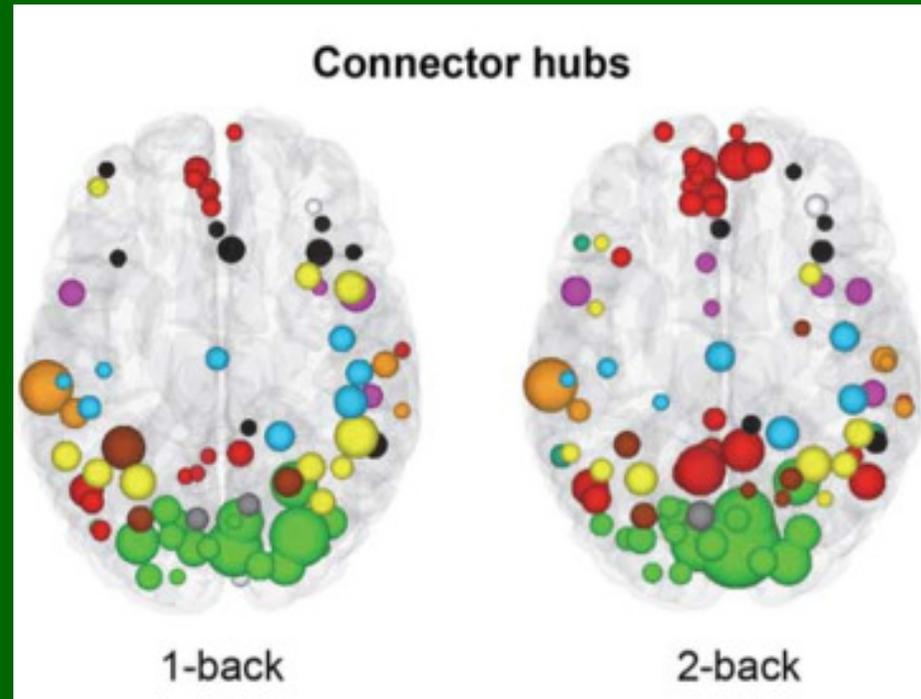
Left: 1-back connector hubs

Right: 2-back connector hubs

Average over 35 *participants*.

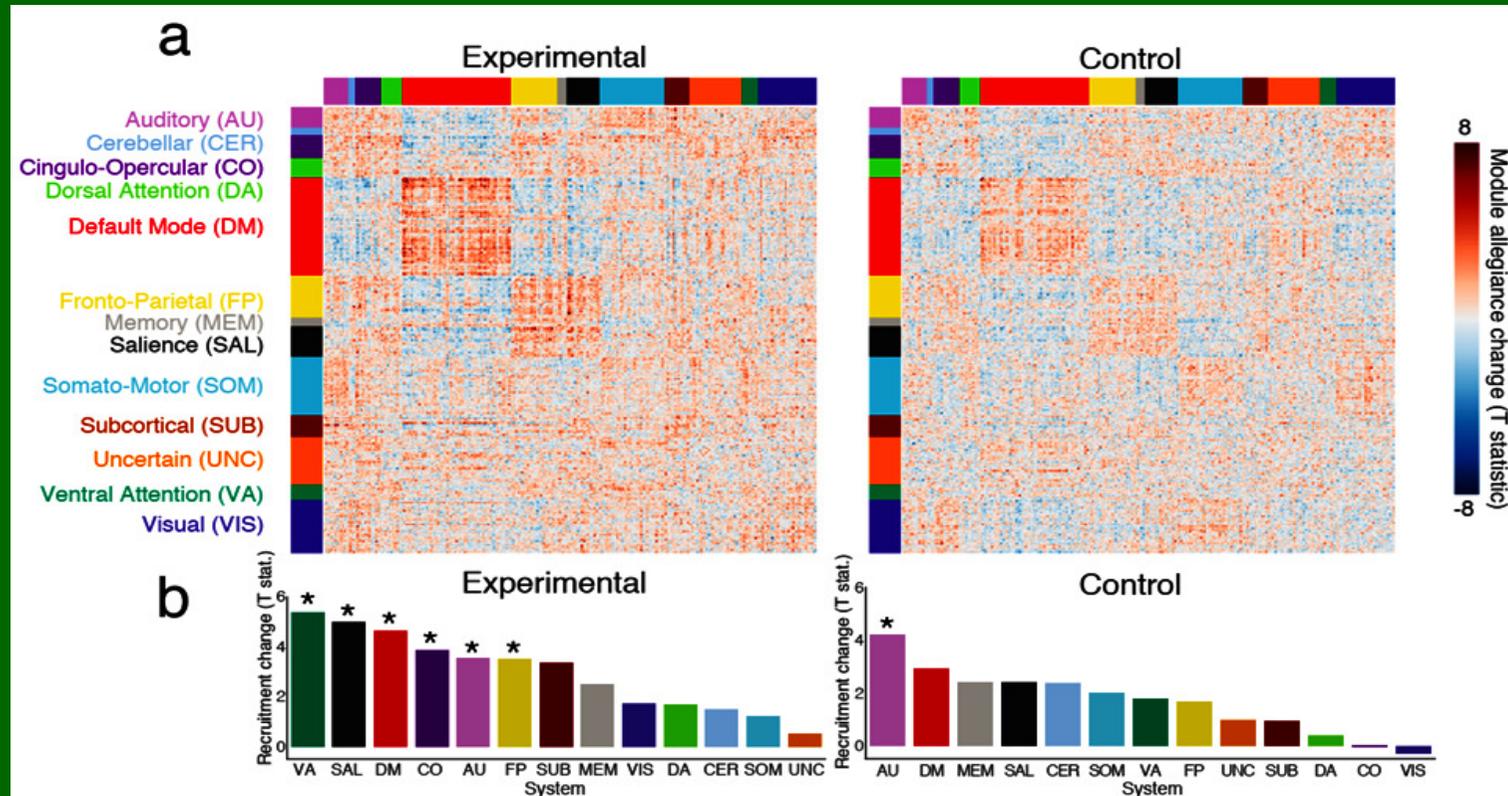
Dynamical change of the landscape of attractors, depending on the cognitive load – System 2 (Khaneman).

DMN areas engaged in global binding!



K. Finc et al, HBM (2017).

Working memory training



Whole-brain changes in module allegiance between the start and after 6-week of working memory training.

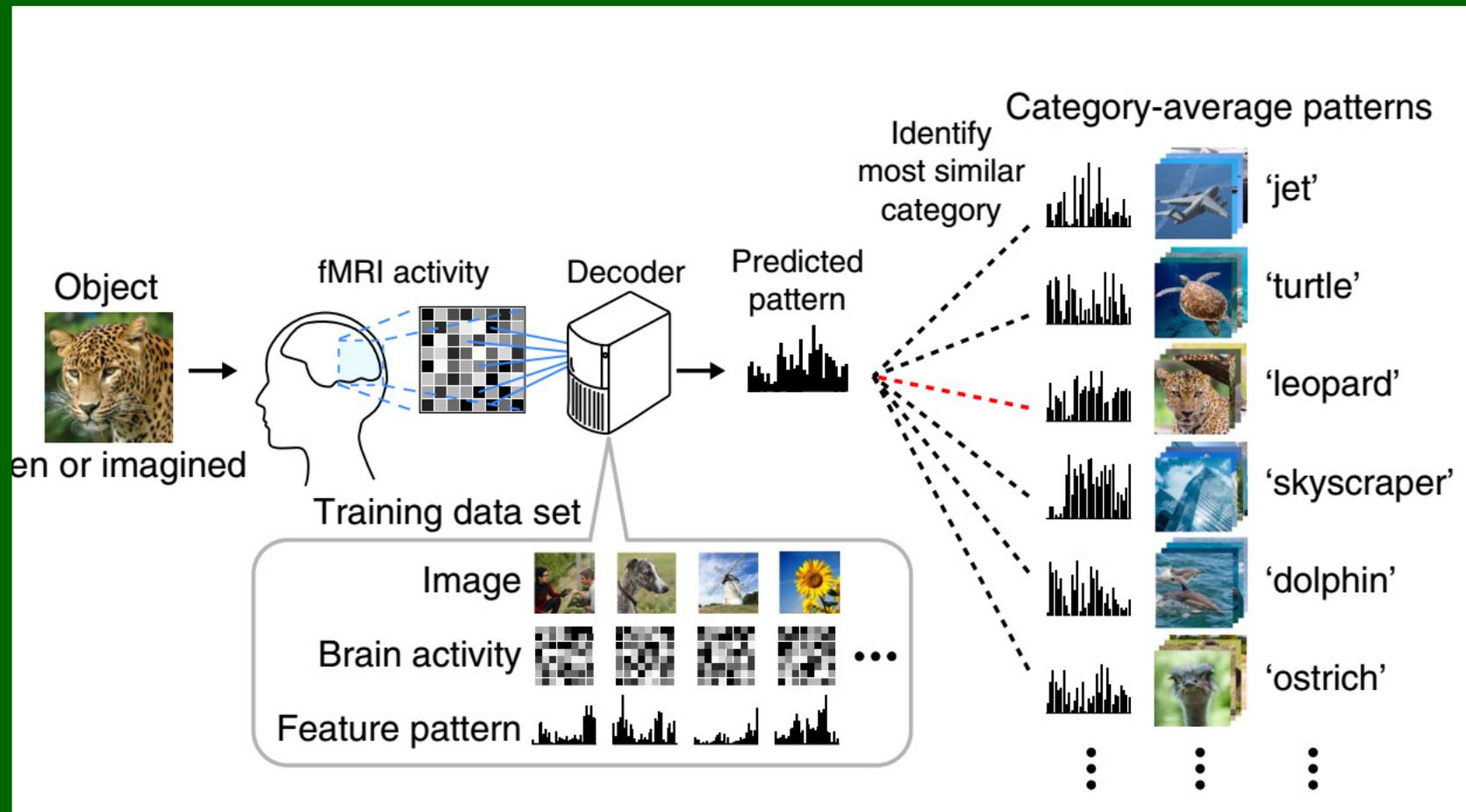
(a) Changes in node allegiance as reflected in the two-tailed *t*-test.

(b) Significant increase * in the ventral attention VA, salience SAL, default mode DM, cingulo-opercular CO, auditory systems AU and fronto-parietal network recruitment.

Finc, Bonna, He, Lydon-Staley, Kühn, Duch, Bassett, Nature Communic. 11 (2020).

Brain activity \leftrightarrow Mental image

fMRI activity can be correlated with deep CNN network features; using these features closest image from large database is selected. Horikawa, Kamitani, Generic decoding of seen and imagined objects using hierarchical visual features. Nature Comm. 2017.



Decoding Dreams



Decoding Dreams, ATR Kyoto, Kamitani Lab. fMRI images analysed during REM phase or while falling asleep allows for dream categorization (~20 categories).
Dreams, thoughts ... can one hide what has been seen and experienced?

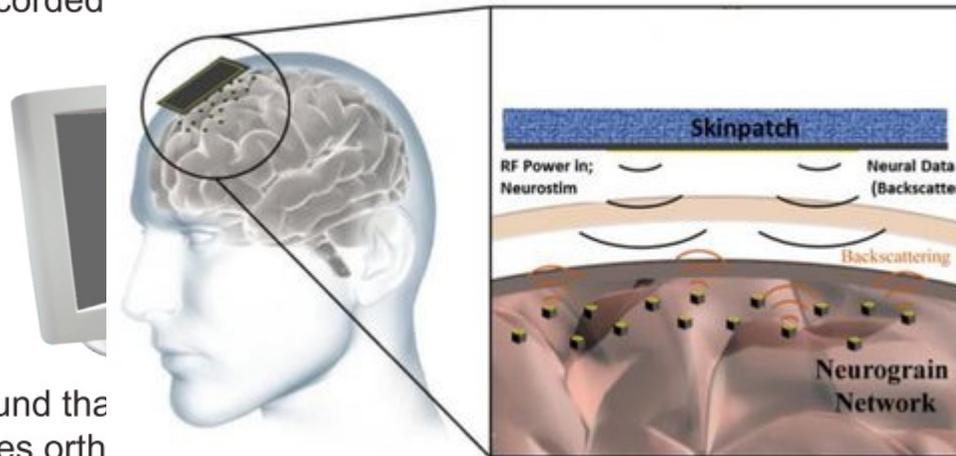
Neural screen

Features are discovered, and their combination remembered as face, but detailed recognition needs detailed recording from neurons – 205 neurons in various visual areas used.

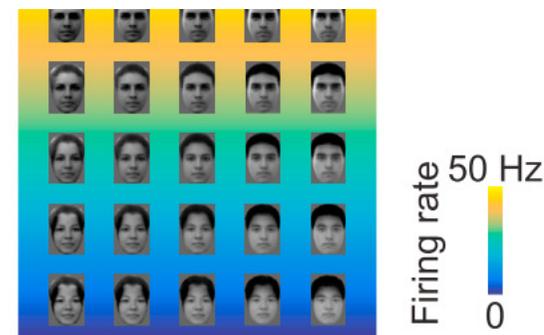
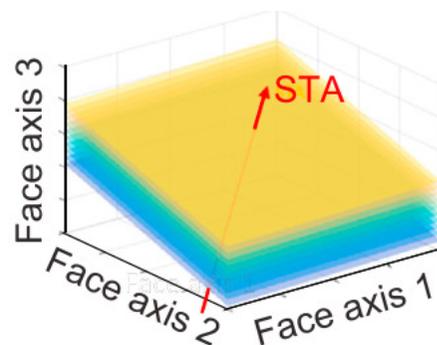
L. Chang and D.Y. Tsao, “The code for facial identity in the primate brain,” *Cell* 2017

Elon Musk Neuralace, DARPA projects: put million nanowires in the brain! Use them to read neural responses, 10% will activate neurons.

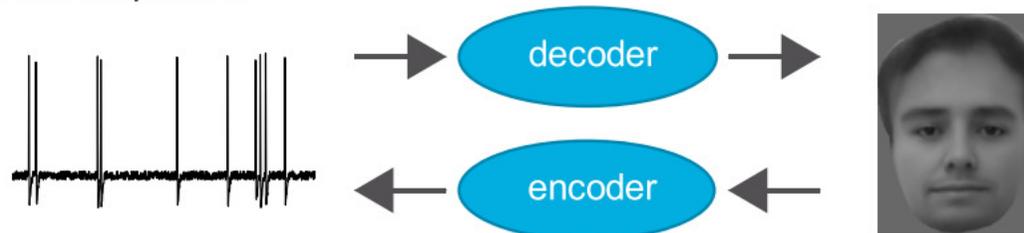
1. We recorded patches



2. We found the to changes orth

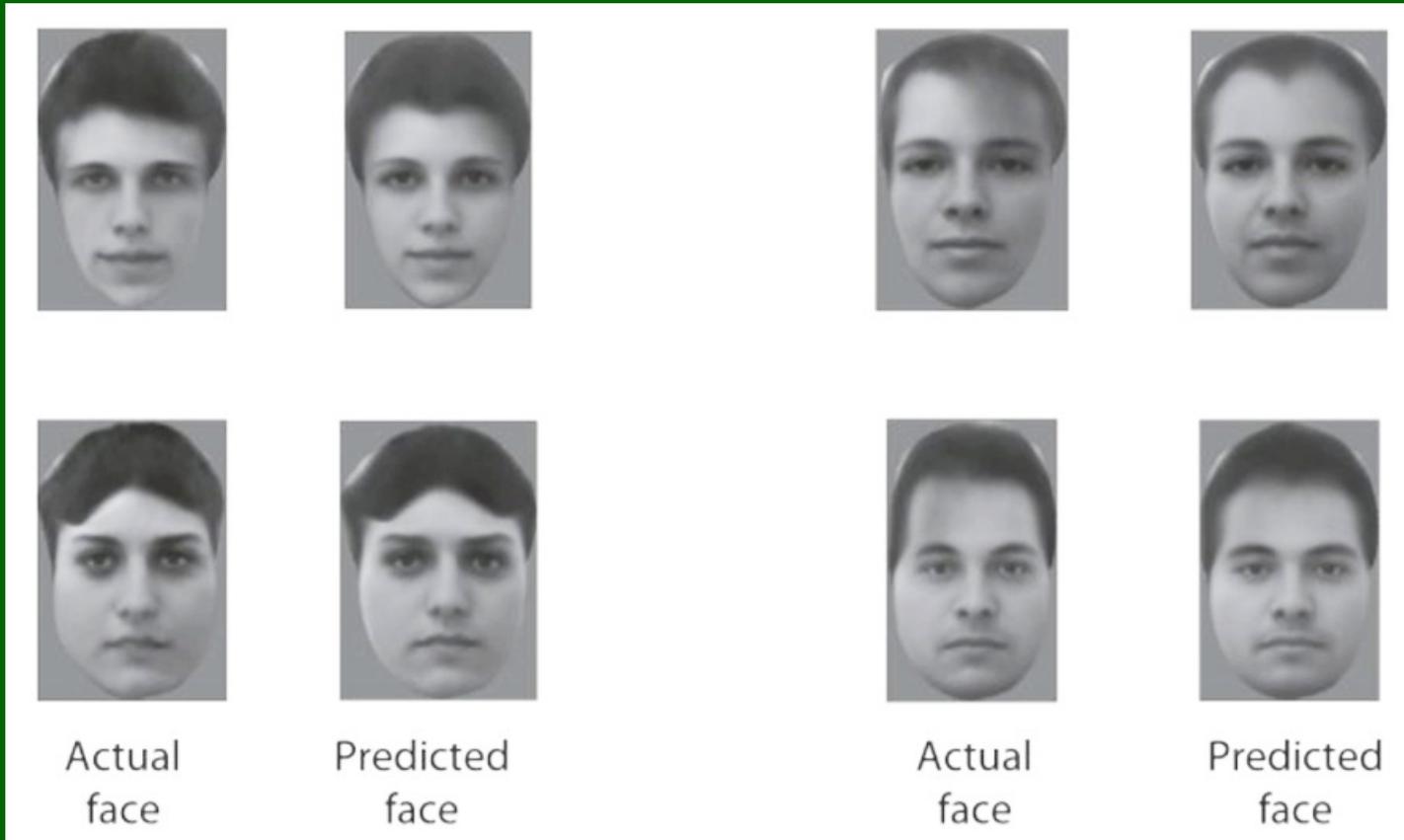


3. We found that an axis model allows precise encoding and decoding of neural responses



Mental images

Facial identity is encoded via a simple neural code that relies on the ability of neurons to distinguish facial features along specific axes in the face space.



L. Chang and D.Y. Tsao, *Cell* 2017

Imagery and brains

How and where are mental images formed?

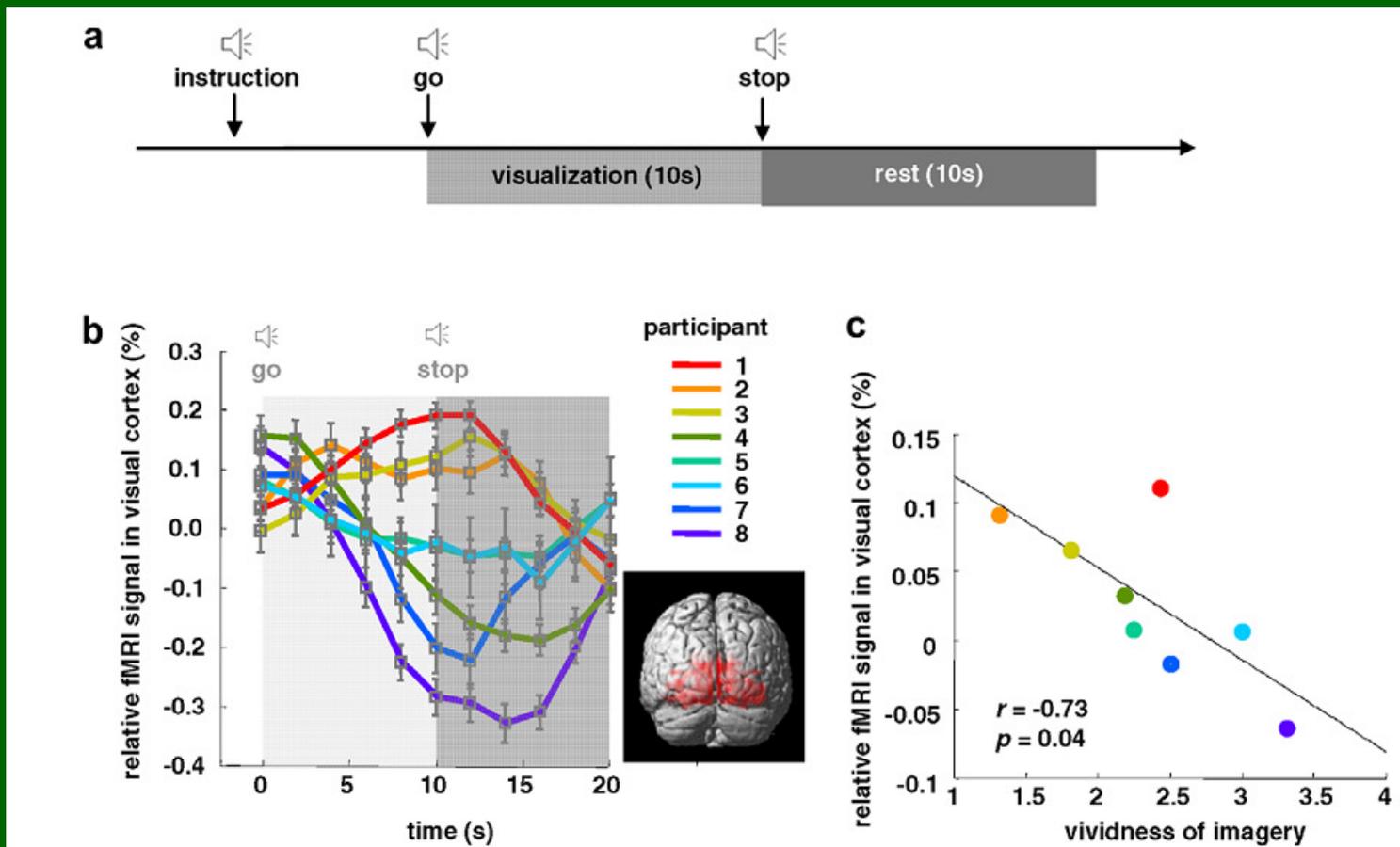
- Borst, G., Kosslyn, S. M, Visual mental imagery and visual perception: structural equivalence revealed by scanning processes. *Memory & Cognition*, 36, 849-862, 2008.

The present findings support the claim that image representations depict information in the same way that visual representations do.

- Cui, X et al. (2007) Vividness of mental imagery: Individual variability can be measured objectively. *Vision Research*, 47, 474-478.

Reported Vividness of Visual Imagination (VVIQ) correlates well with the early visual cortex activity relative to the whole brain activity measured by fMRI ($r=-0.73$), and the performance on a novel psychophysical task.

Findings emphasize the importance of examining individual subject variability.



Reported Vividness of Visual Imagination (VVIQ) correlates well with the early visual cortex (V1) activity relative to the whole brain activity measured by fMRI ($r = -0.73$), and the performance on a novel psychophysical task. Findings emphasize the importance of examining individual subject variability.

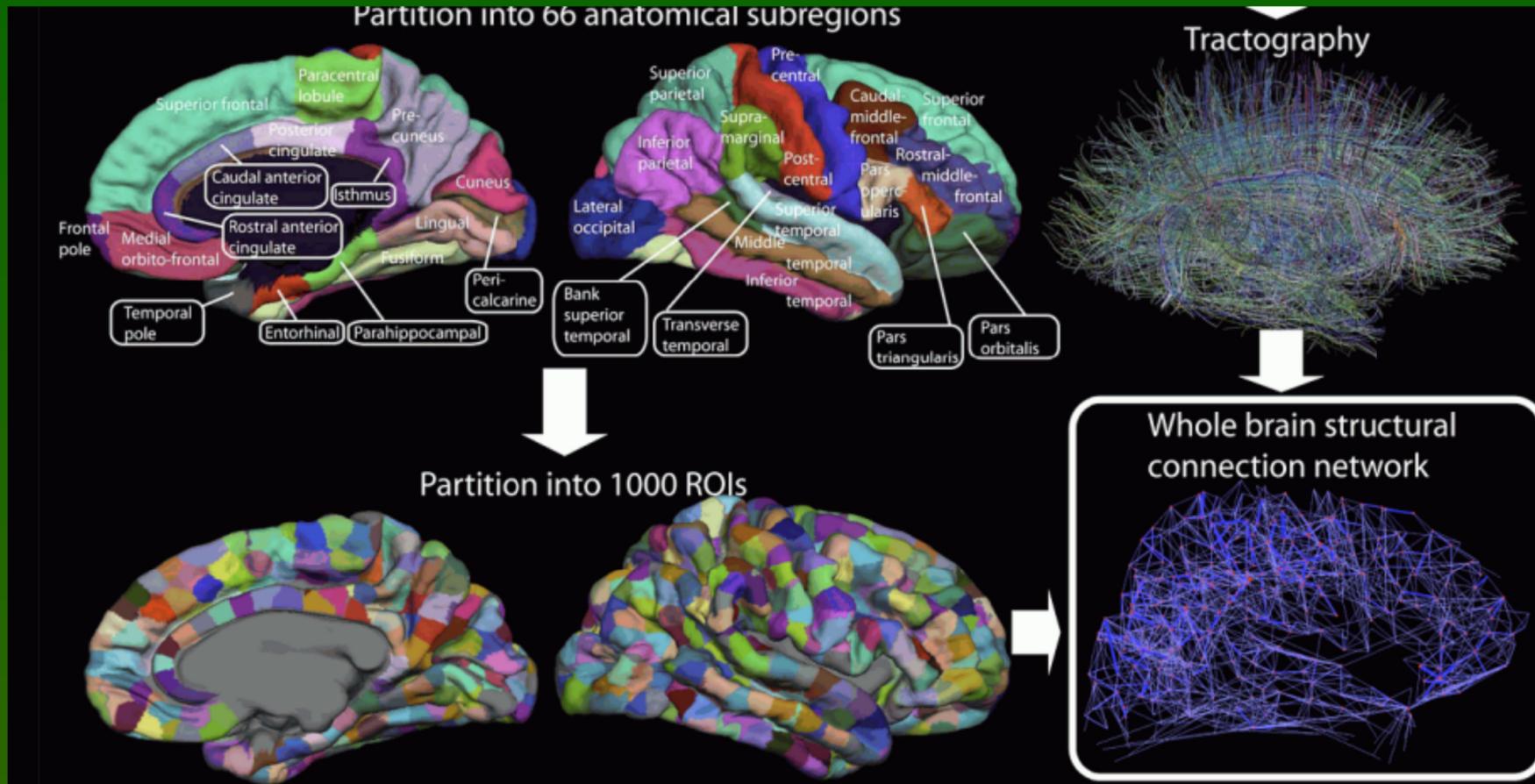
Poor perceptual imagery: why? Weak top-down influences?

Unable to draw from memory, describe details, faces, notice changes, etc.

Brains are formed by experience

Each brain is unique, due to genetic and environmental factors.

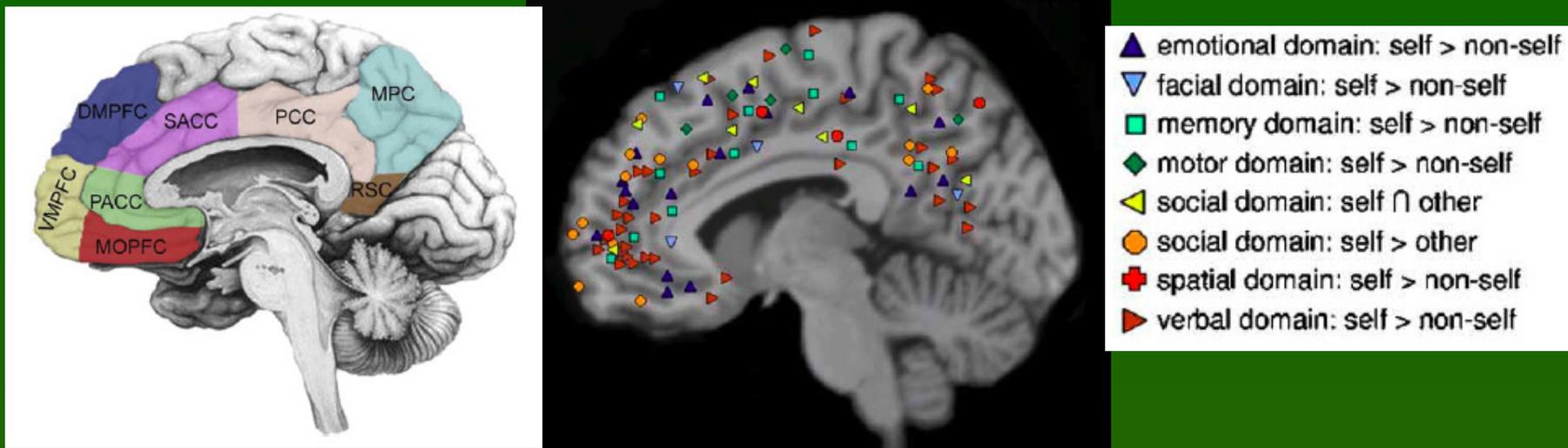
Neural determinism: spontaneous thought



Sporns O, Tononi G, Kötter R (2005) The human connectome: A structural description of the human brain. PLoS Comput Biol 1: 245–251

What our Self knows?

Northoff *et.al*, Self-referential processing in our brain - a meta-analysis of imaging studies on the self. *Neuroimage* 31, 440, 2006

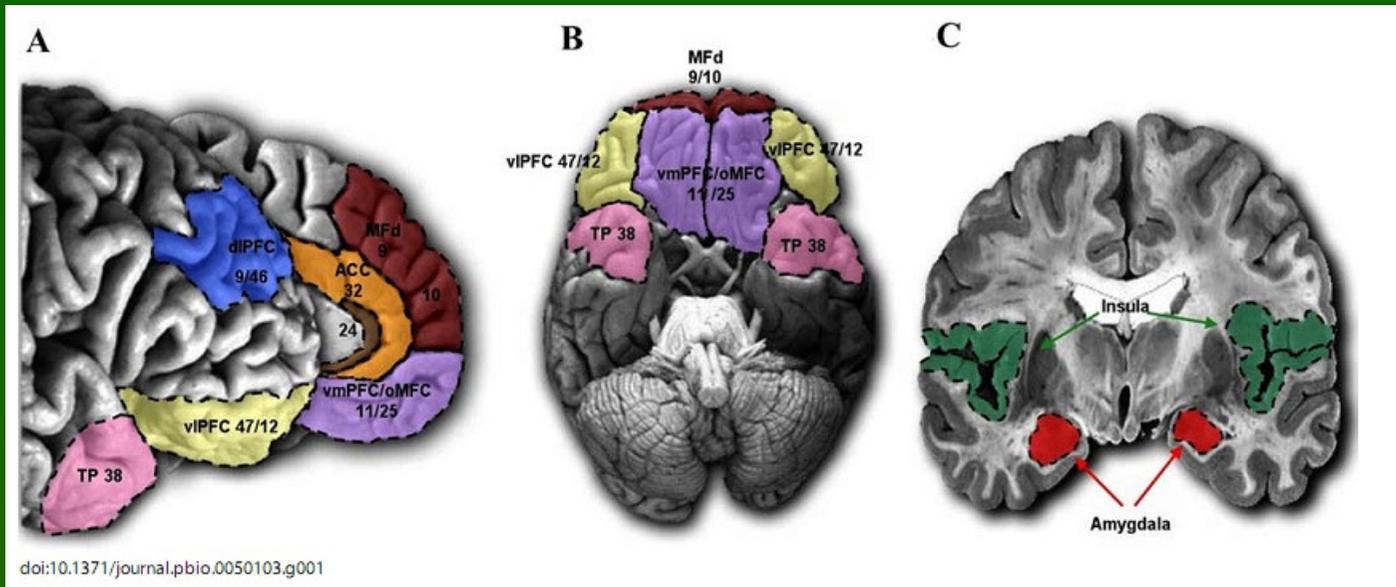


CMS, Cortical Midline Structures, are all involved in the verbal, spatial, emotional and face recognition test when self and others are distinguished. These structures are rarely damaged and are in between the rest of the cortex and limbic/brain stem structures.

Proto-self: body; autobiographical: memory; social: relations.

Brain and antisocial behavior

Mobbs D, Lau HC, Jones OD, Frith CD,
Law, Responsibility, and the Brain. PLoS Biol 5(4): e103 (2007)



Prefrontal cortex (PFC) enables moral and rational reasoning and behavior. Damage to PFC leads to acquired sociopathy, impulsive affective criminals. Damage to amygdala leads to poor empathy and low fear, typical for psychopathic emotionless criminals.

Estimation: **~25% of all prisoners in the USA** fall in these two categories, frequently due to birth complication and trauma.

Will is just another feeling



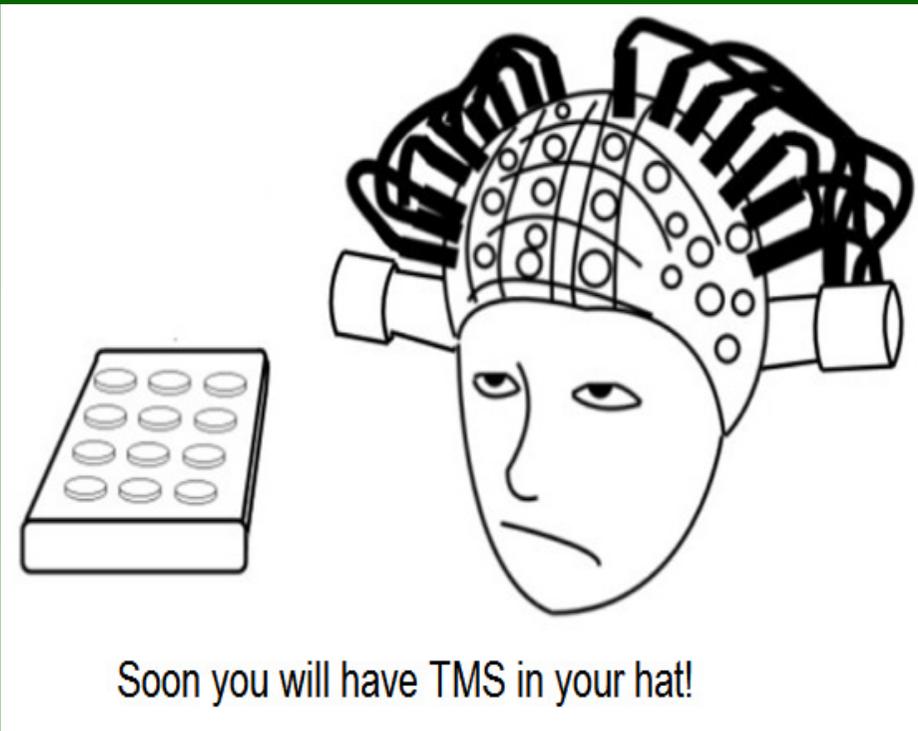
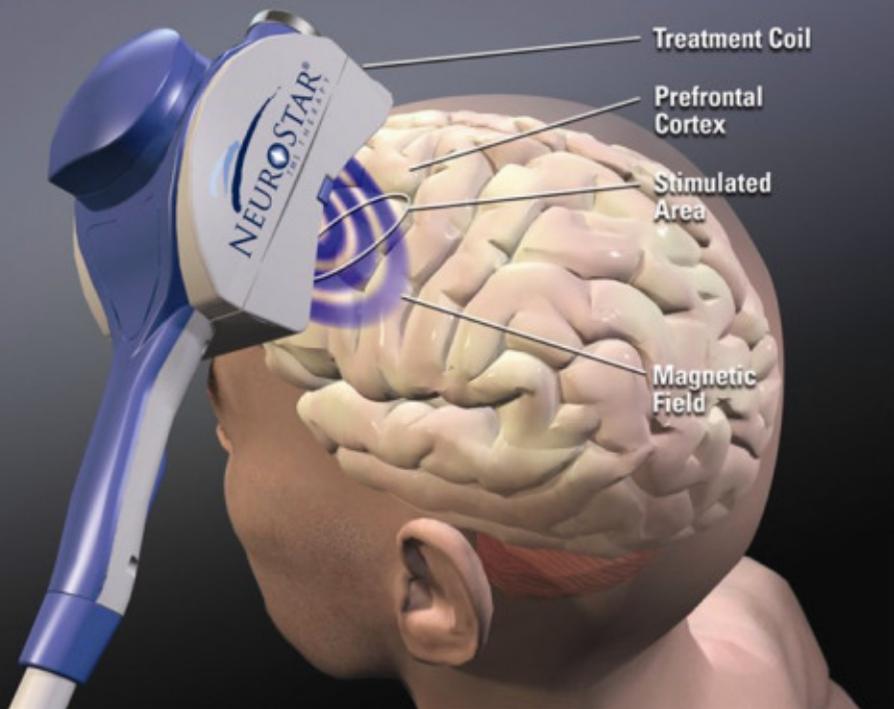
Wegner DM, *The illusion of conscious will*. MIT Press(2002)

The feeling of agency can be deceiving!

- We may be acting but do not realize that we are. Examples: **ouija board**, facilitated communication; water divination, hypnotism.
- We are not acting, but think that we are:
Subjects may be induced to believe that they have performed some actions, or that their actions are achieving far more than they in fact are.

Conscious acts of will are never the direct causes of our actions.
Instead, both conscious willing and action are the effects of a common unconscious causes – usually too many to determine all.

Mind control



TMS stimulations of motor cortex: even if one side of the brain is selected and 80% of time one hand is used the choice seems to be free ...

Our will is just another feeling, resulting from attention to the state of the pre-supplementary motor cortex (**Pre-SMA**).

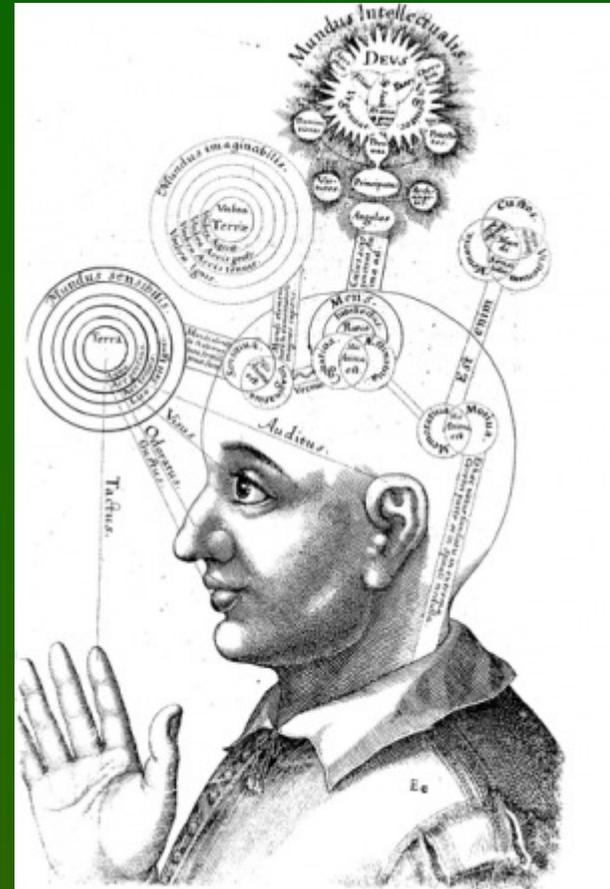
Is consciousness causing actions?

Estimate: Our psychological reactions from moment to moment... are 99.44% automatic (J. Bargh, 1997).

Sequential conscious thinking in comparison to the unconscious parallel processing cannot accomplish much; “strictly speaking, conscious thought does not exist”, conscious thought is merely some unconsciously processed information or brain state that wins the competition to enter awareness, the highest control level. (Dijksterhuis et al. 2005)

Baumeister, R. F., Masicampo, E. J., & Vohs, K. D.
Do conscious thoughts cause behavior?
Annual Review of Psychology (2011).

Answer: yes, but not directly, we have no conscious control over what comes to our mind, but conscious thoughts influence mental states.

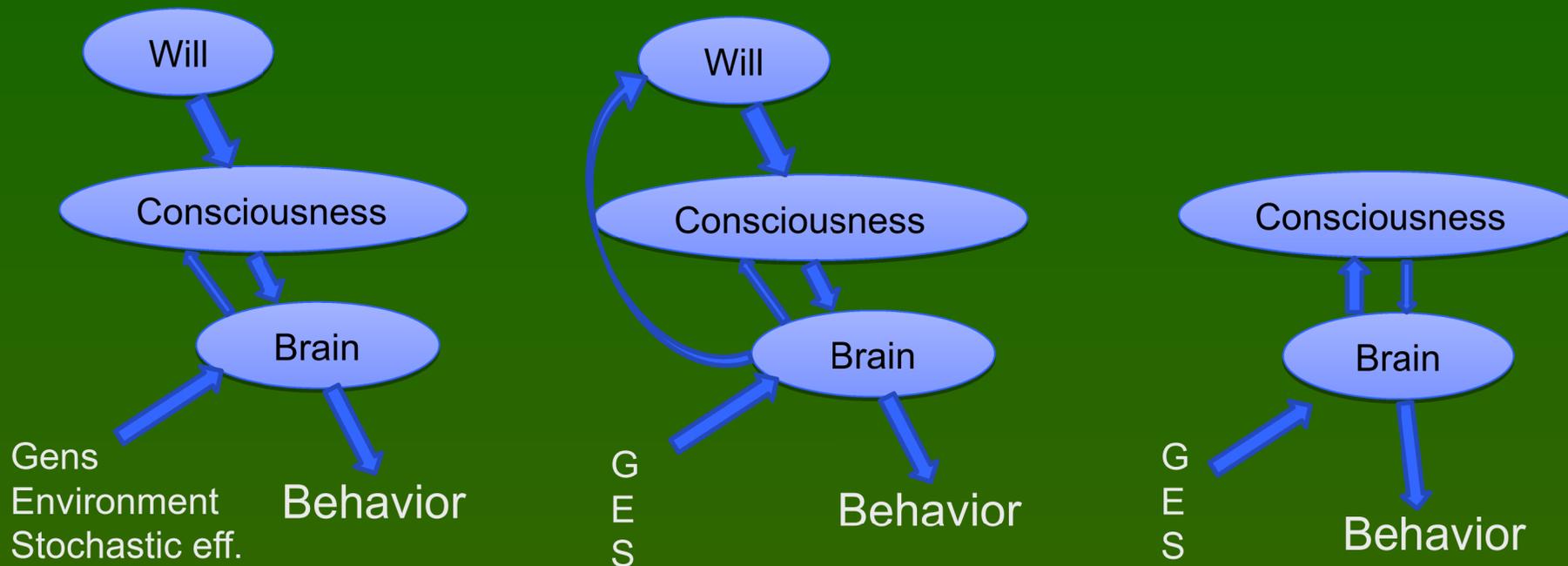


Brain and will

Brains exists solely to ensure survival, not to understand ourselves.
Only by looking from outside we can understand the brain and draw conclusions about its nature and functions.

Edward Osborne Wilson

What are the options? Naive, reflexive and mechanical.



Personal responsibility



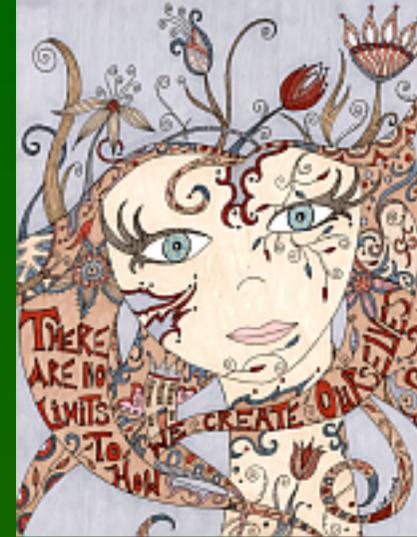
- Traditional view breaks down: there is no “self” or ghost in the machine that pulls the strings.
- Self is one of many processes that brain is implementing, conscious of a small subset of brain processes.
- If the self is not in control then how can it be responsible?
- My brain made me do it! I am not responsible!
- To what degree and in what sense can we speak of free choices?

Solutions: even more responsibility?

- The whole person is responsible, not just the ego or self, idea of me.
- We are responsible for our actions, good intentions are not enough.
- We are responsible for who we become, our own development!
- The brain has to educate itself and to “know oneself” better.
- We are responsible for the development of our children, setting out good examples and model roles.
- Spiritual development is our moral obligation.

"Self" without limits

- Decisions are made by the whole brain, not all decisions or resolutions are consciously realized.
- I can control my behavior according to my values, but first I should make it conscious \Leftrightarrow understand myself.
- Free will (compatibilist style) = conscious control of behavior in accord with acquired beliefs and values.



Self is a complex of brain states and relations between these states.

Boundaries of self do not make much sense, all strongly coupled processes are part of big mind.

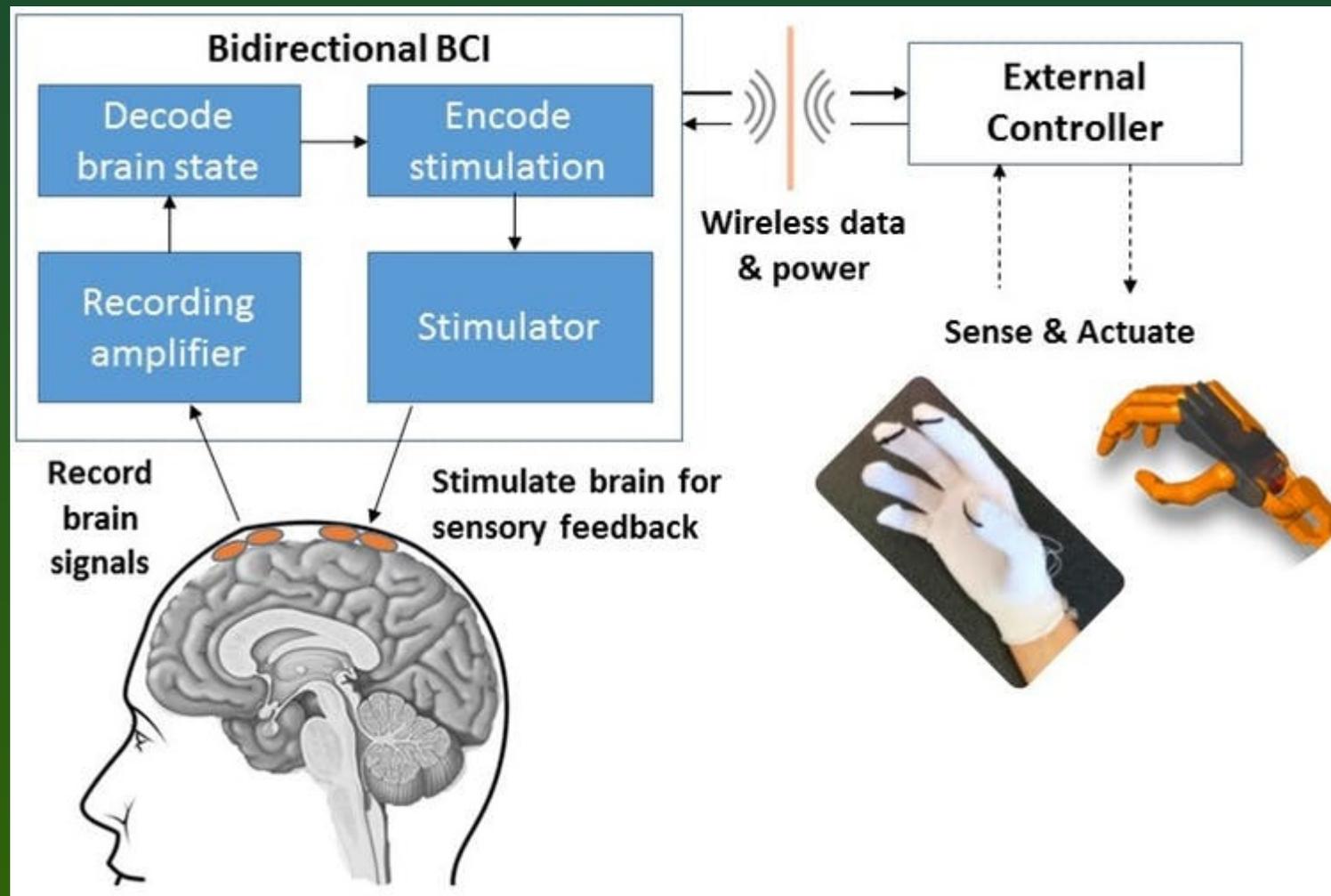
Genetics + environmental relations
Social relations

All processes in the brain that influence behavior

I =
model of
self

Behavior, big mind

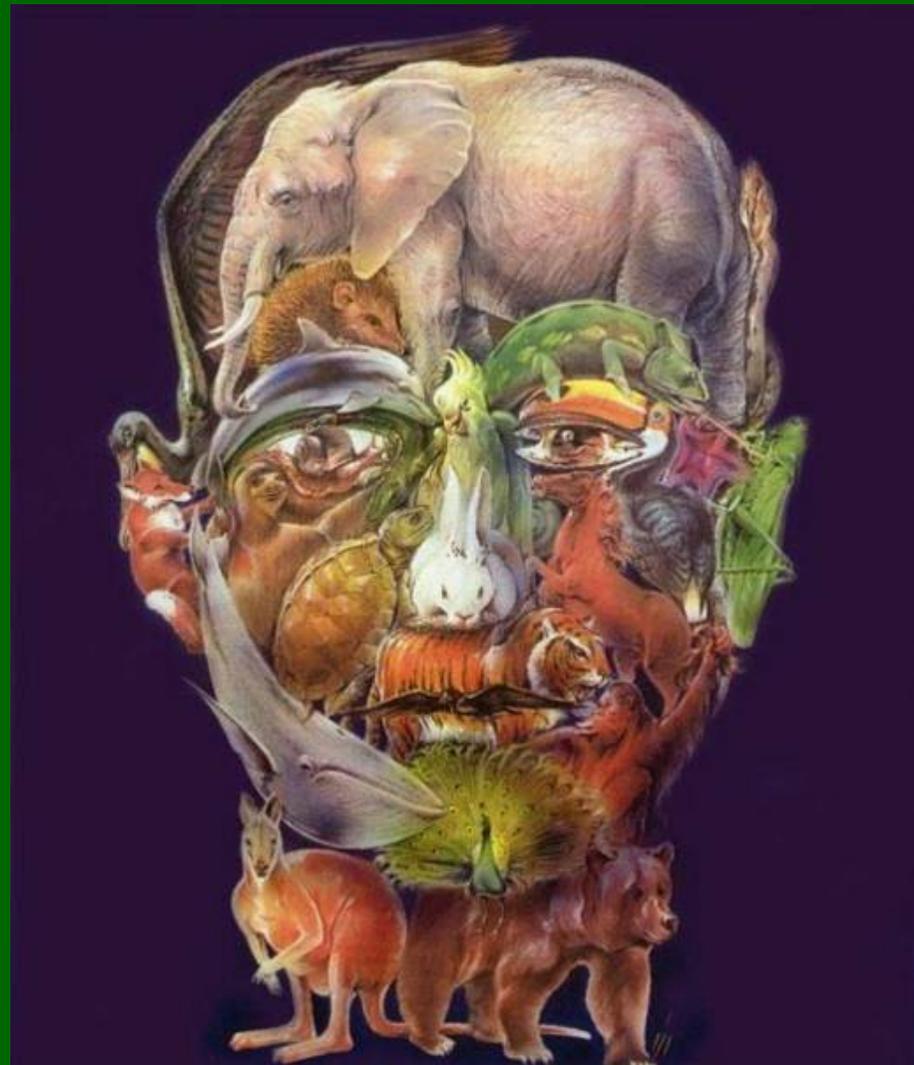
Brain-Computer-Brain Interfaces



Closed loop system with brain stimulation for self-regulation.
Body may be replaced by sensory signals in Virtual Reality.



**Thank
you for
stretching
your
imagination**



Google: [Włodzisław Duch](#) => Papers/presentations/lectures