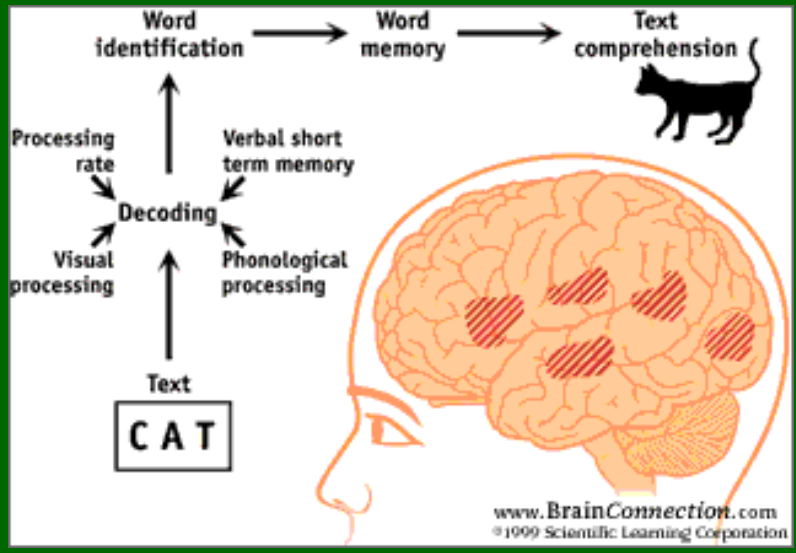
Selected topics in cognitive neuroscience and biomodeling

L15: Consciousness



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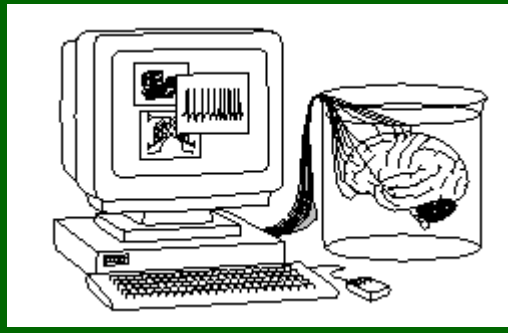
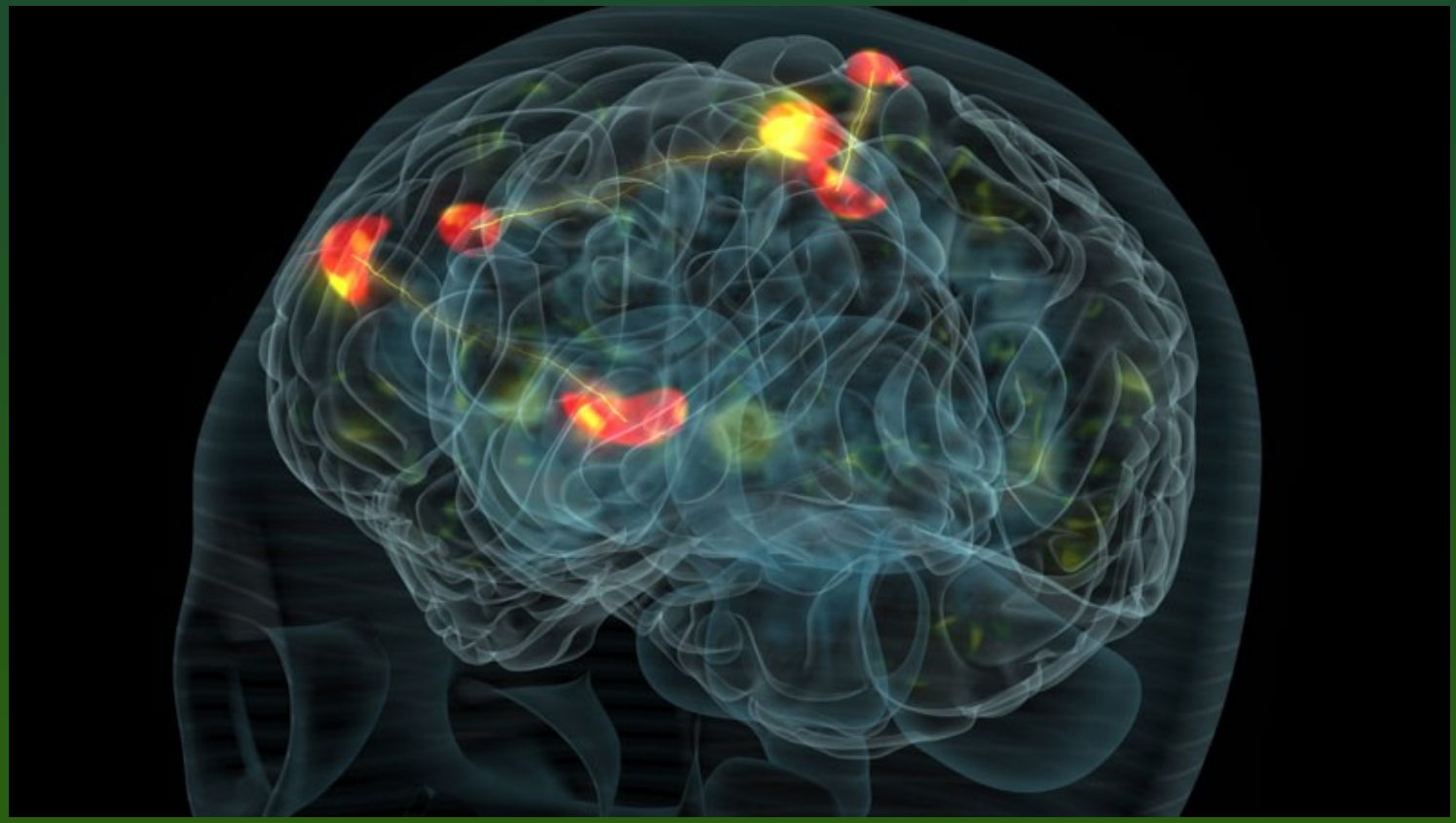
What it will be about

1. Consciousness, will, and complex cognition.
2. Summary.

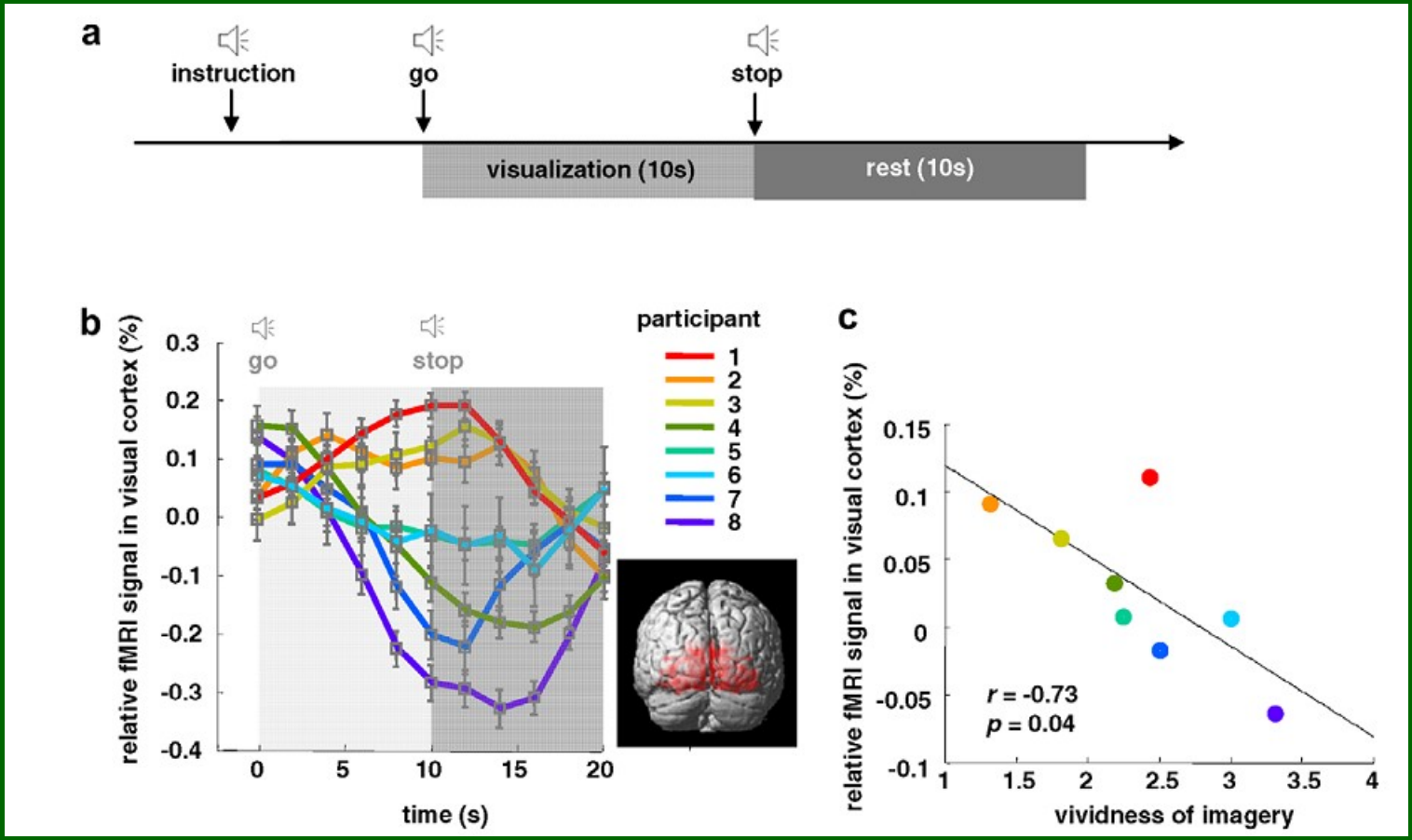


Mental state: strong coherent activation



Many processes go on in parallel, controlling homeostasis and behavior. Most are automatic, hidden from our Self. What goes on in my head?

Various subnetworks compete for access to the highest level of control - consciousness, the winner-takes-most mechanism leaves only the strongest. How to extract stable intentions from such chaos? BCI is never easy.



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.

Hierarchical brain structure

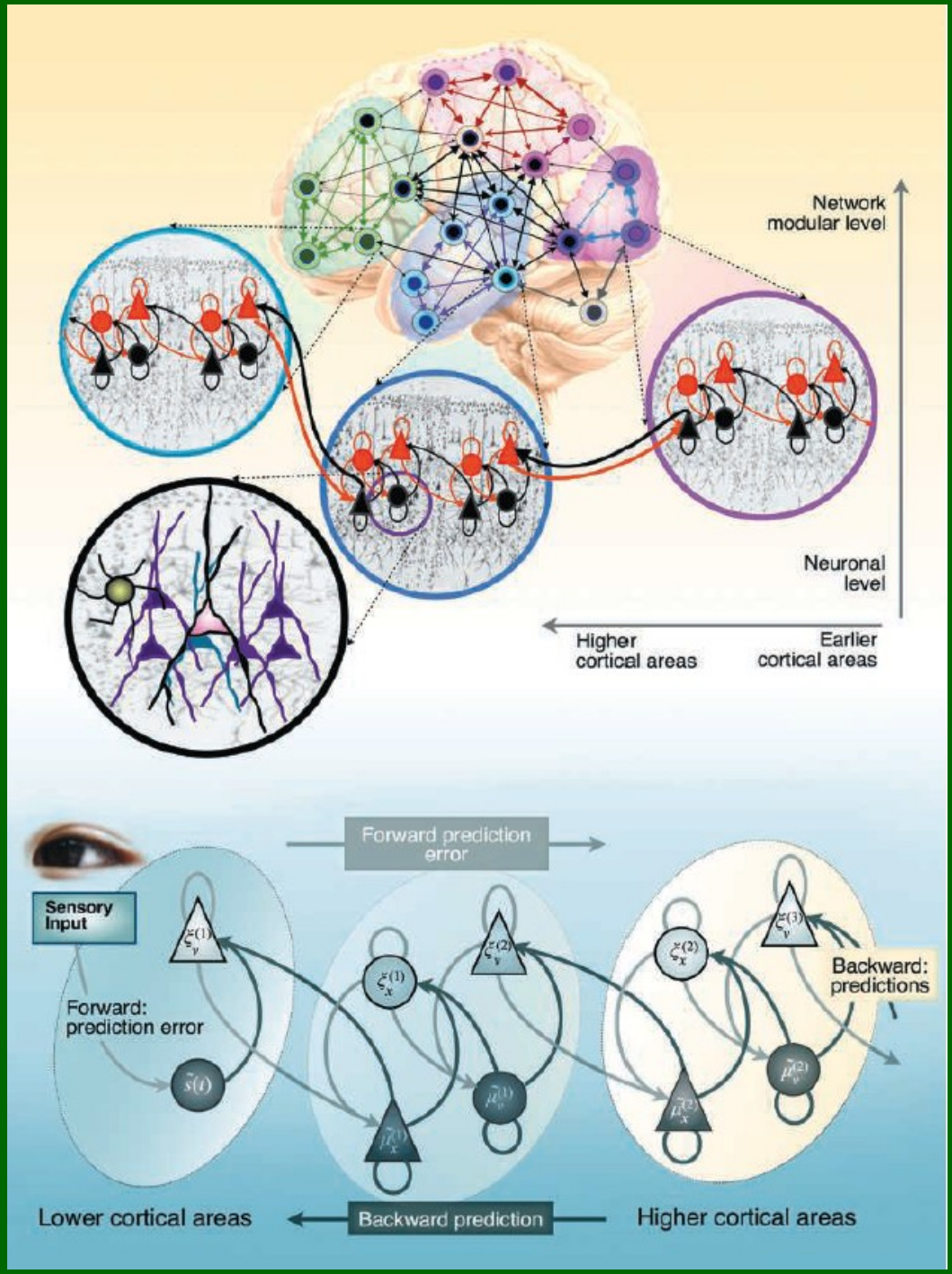
Brains try to predict and learn only when prediction fail.

Back of the brain – forward prediction error.

Front of the brain – backward predictions.

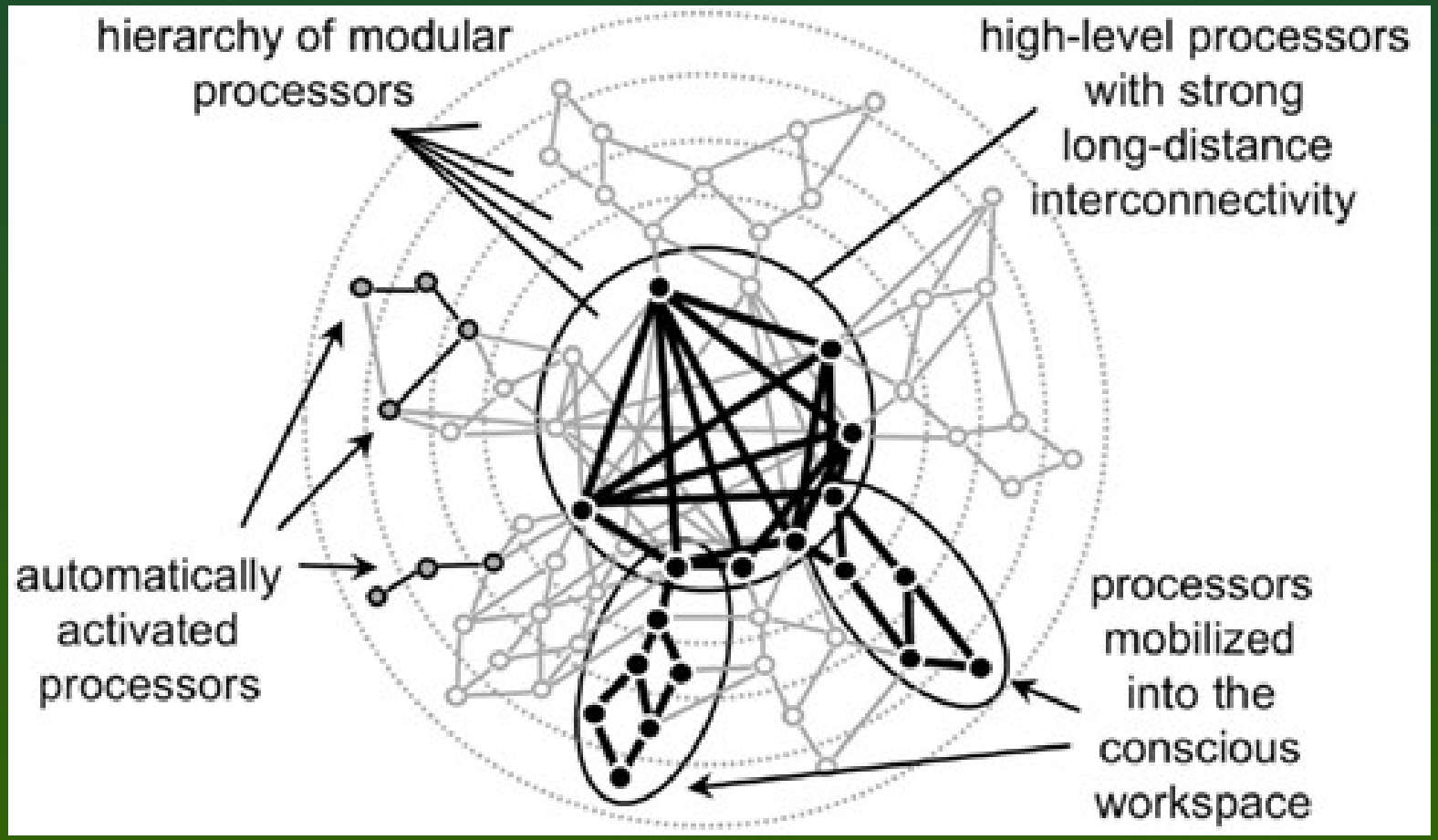
Park H-J, Friston K.

Structural and functional brain networks: from connections to cognition. Science. 2013;342



GNWT

Global Neuronal Workspace Theory (Dehaene et al. 1998)

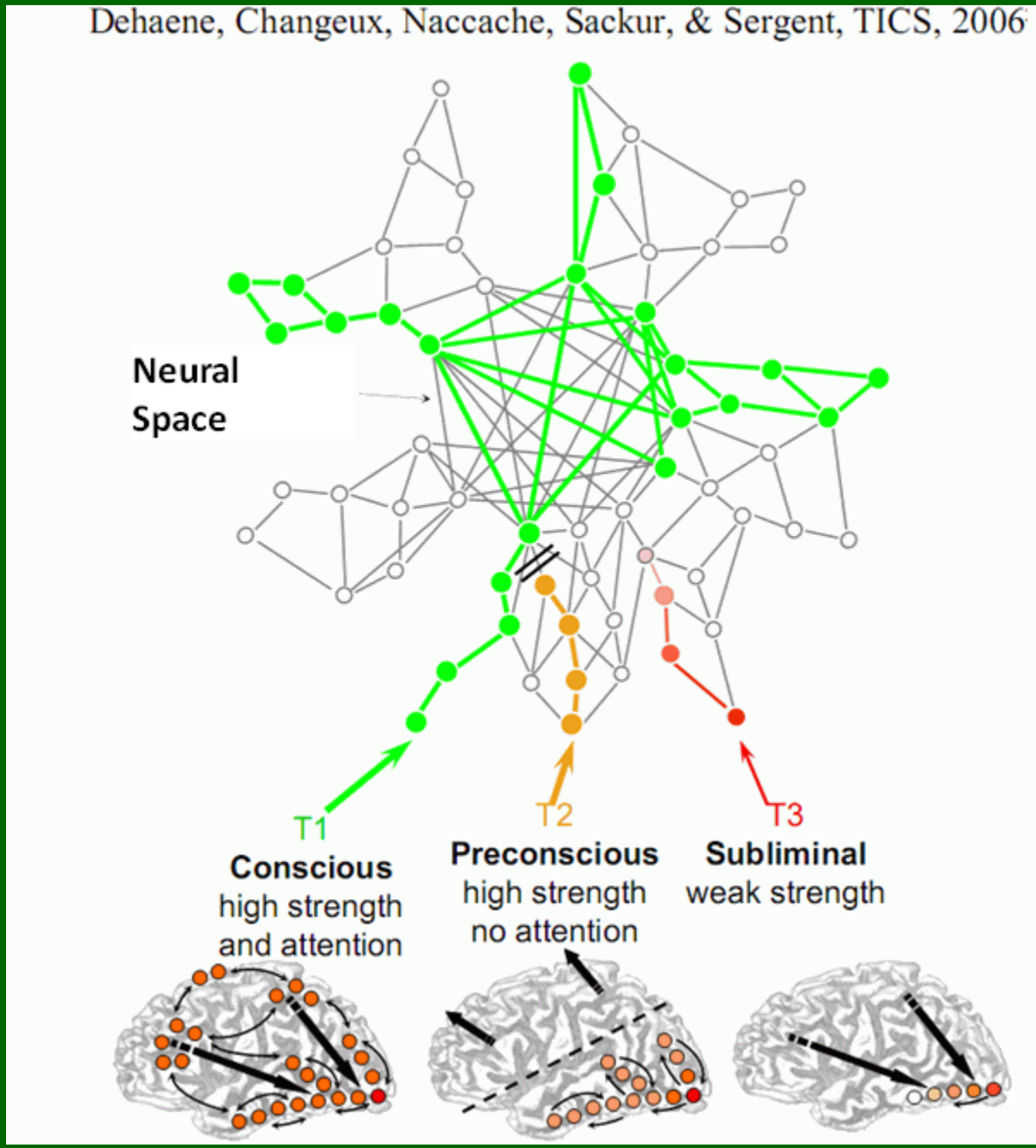


Brain is a substrate in which dynamic states arise - thoughts, feelings and intentions are spatiotemporal brain activations.

Conscious Perception

Very little of what passes through the brain is perceived.
Stimulation and attention (>20 Hz) is needed to create persistent brain states distinguishable from noise.
Perception: rises oscilations to 40 Hz.

C. Gilbert, M. Sigman, Neuron 2007



Role of consciousness

Declarative vs. procedural knowledge

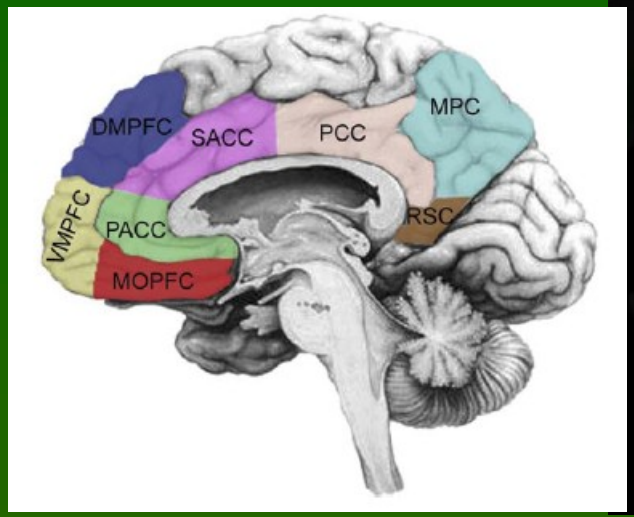
- Declarative: often expressed symbolically (words, gestures).
- Procedural: more oriented towards sequences of actions.

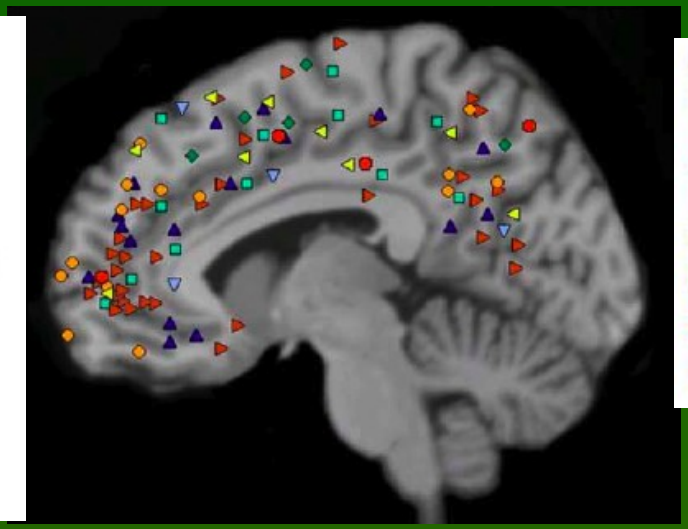
Explicit vs. implicit knowledge.

- Controlled action relies on explicit and declarative knowledge.
- Automatic actions rely on implicit and procedural knowledge.
- Consciousness => states existing for a noticeable period of time, integrating reportable sensory information about different modalities, with an influence on other processes in the brain.
- Each system, which has internal states and is complex enough to comment on them, will claim that it's conscious.
- Processes in the prefrontal cortex and the hippocampus can be recalled as a brain state or an episode, can be interpreted (associated with concept representation).

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



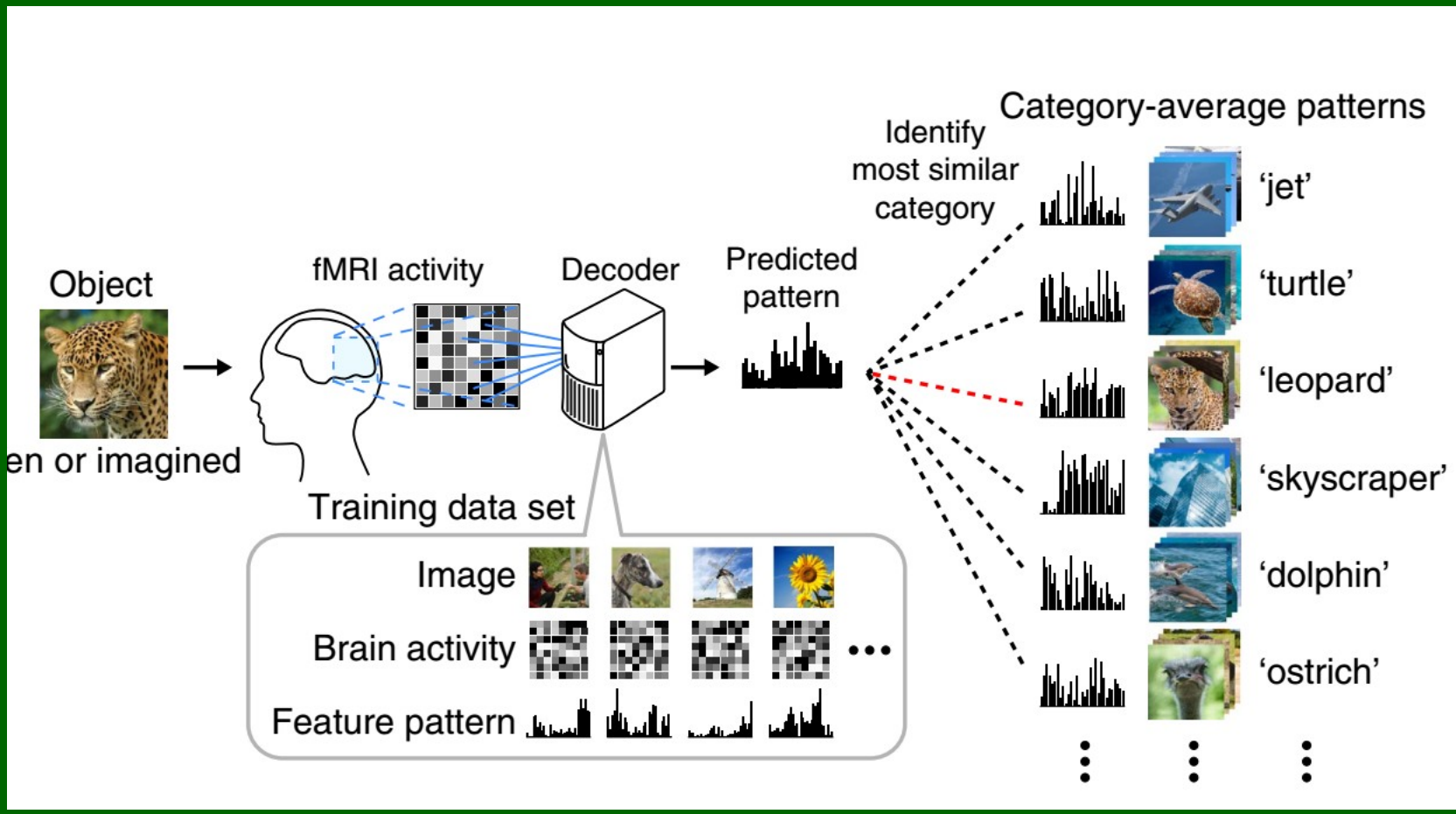


CMS, Cortical Midline Structures, are all involved in the verbal, spatial, emotional and face recognition test when self and others are distinguished. These structures are rarely damaged and are in between the rest of the cortex and limbic/brain stem structures.

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

Brain activity ⇔ 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).

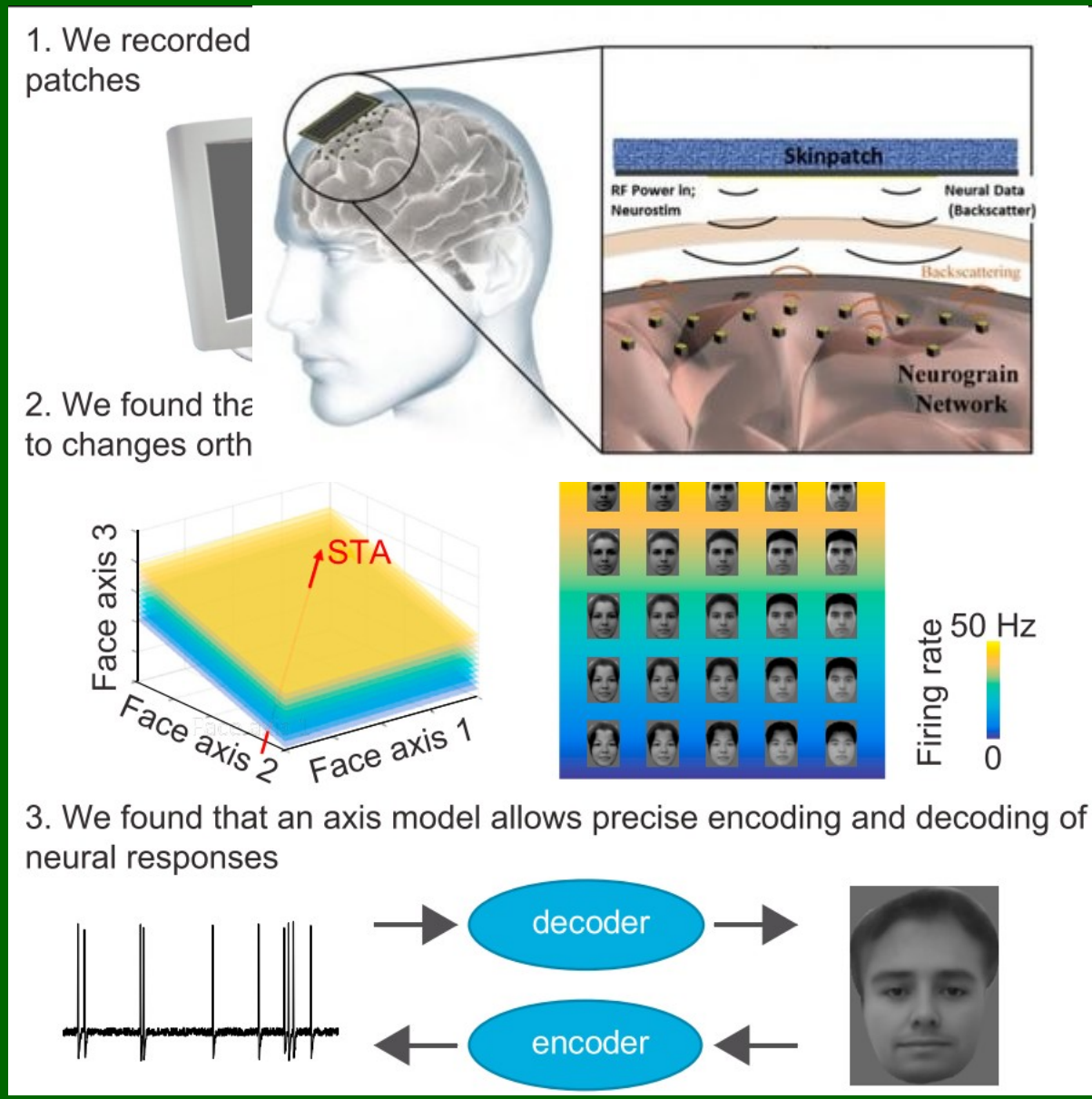
Dreams,thoughts … can one hide what has been seen and experienced?

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.

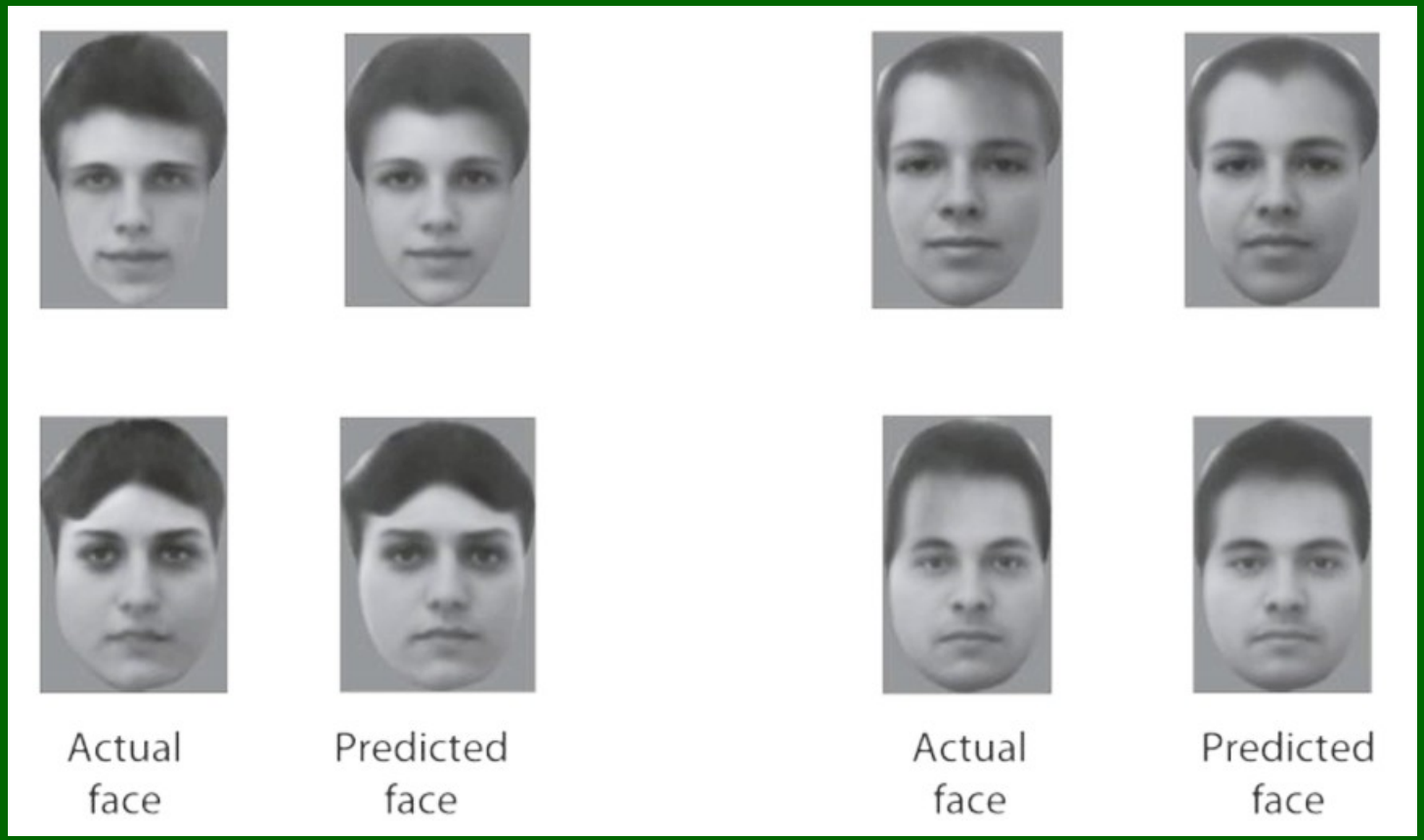
L. Chang and D.Y. Tsao, "The code for facial identity in the primate brain," *Cell* 2017

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



Mental images

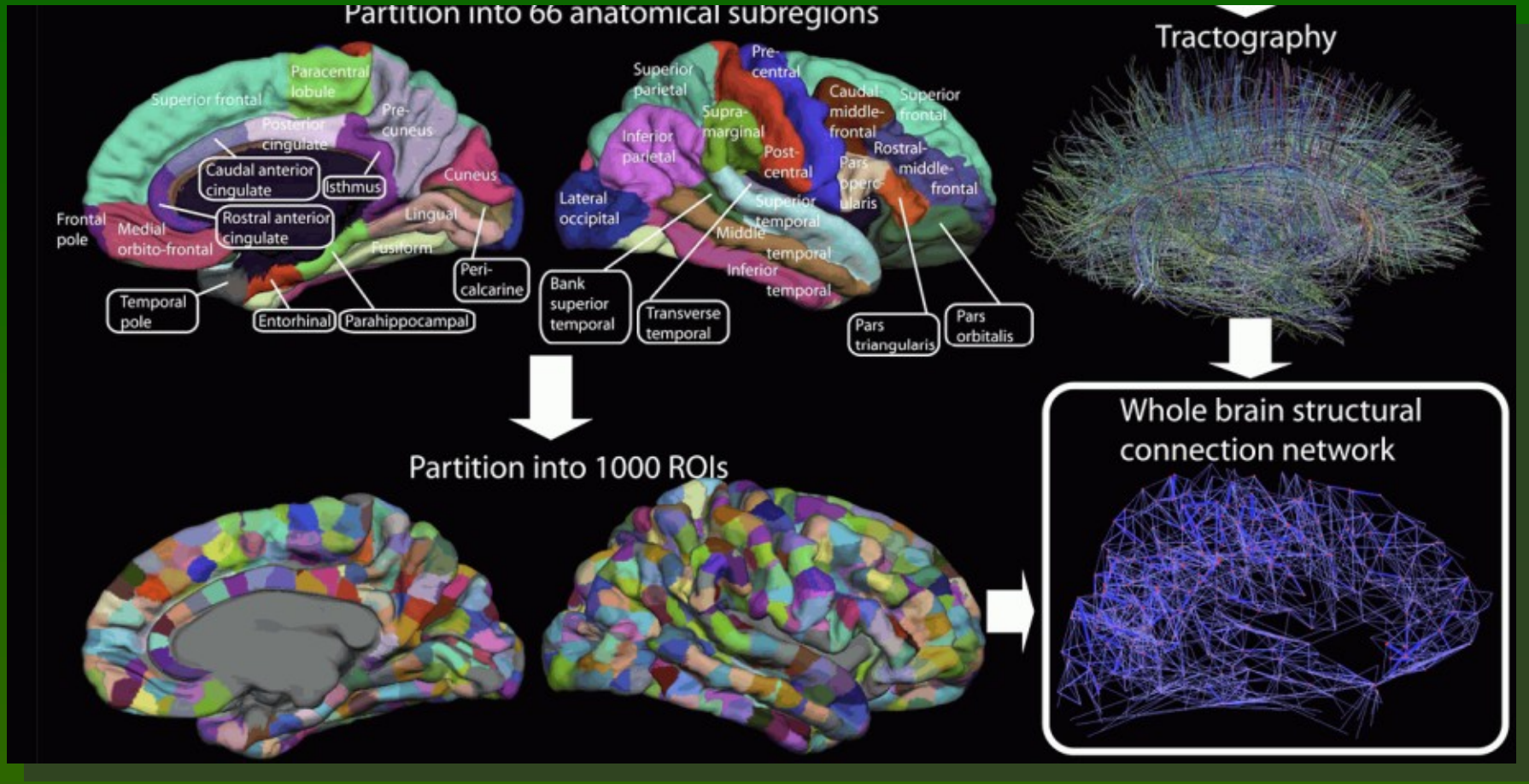
Facial identity is encoded via a simple neural code that relies on the ability of neurons to distinguish facial features along specific axes in the face space.



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

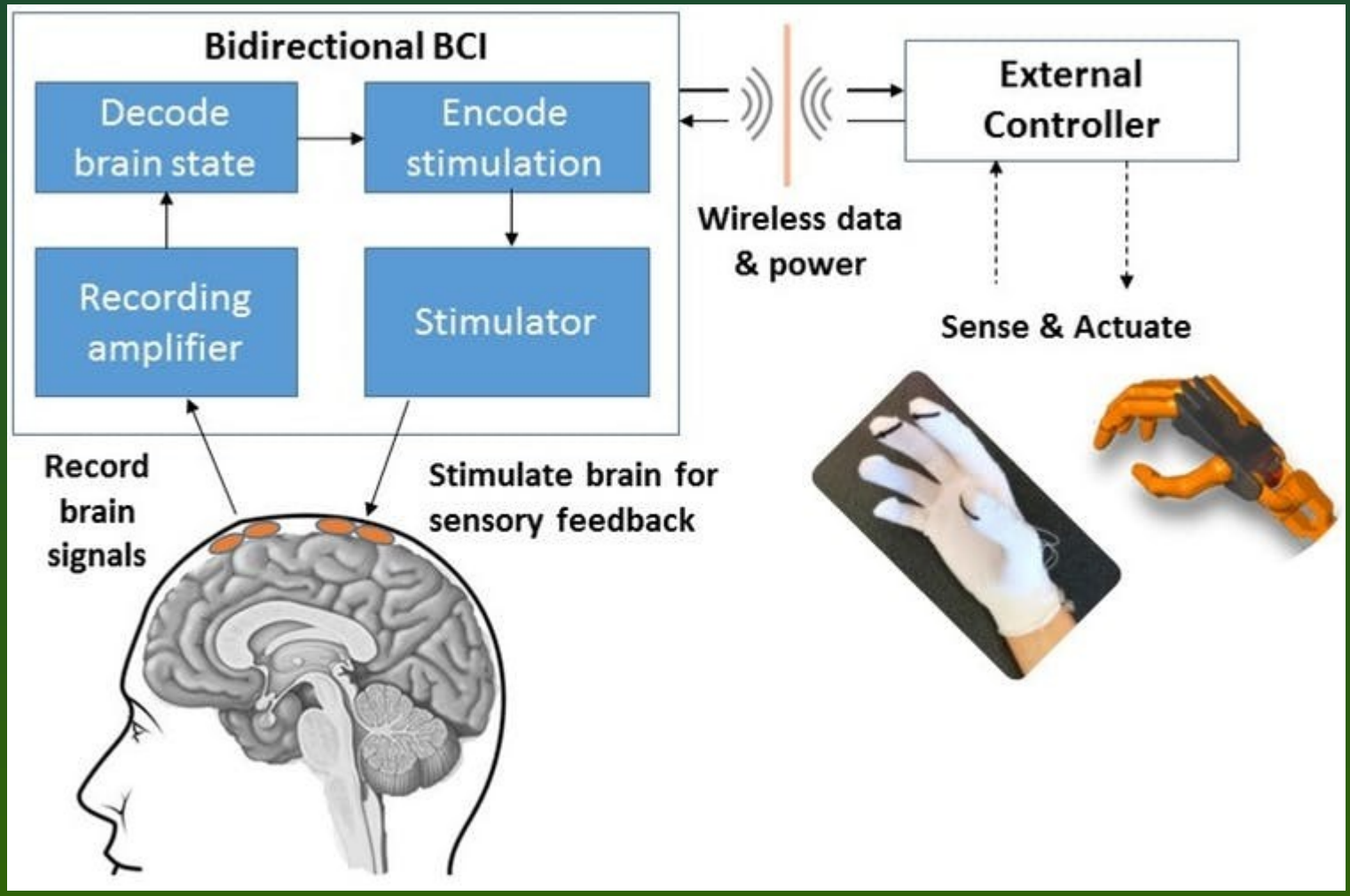
Brains are formed by experience

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

Brain-Computer-Brain Interfaces



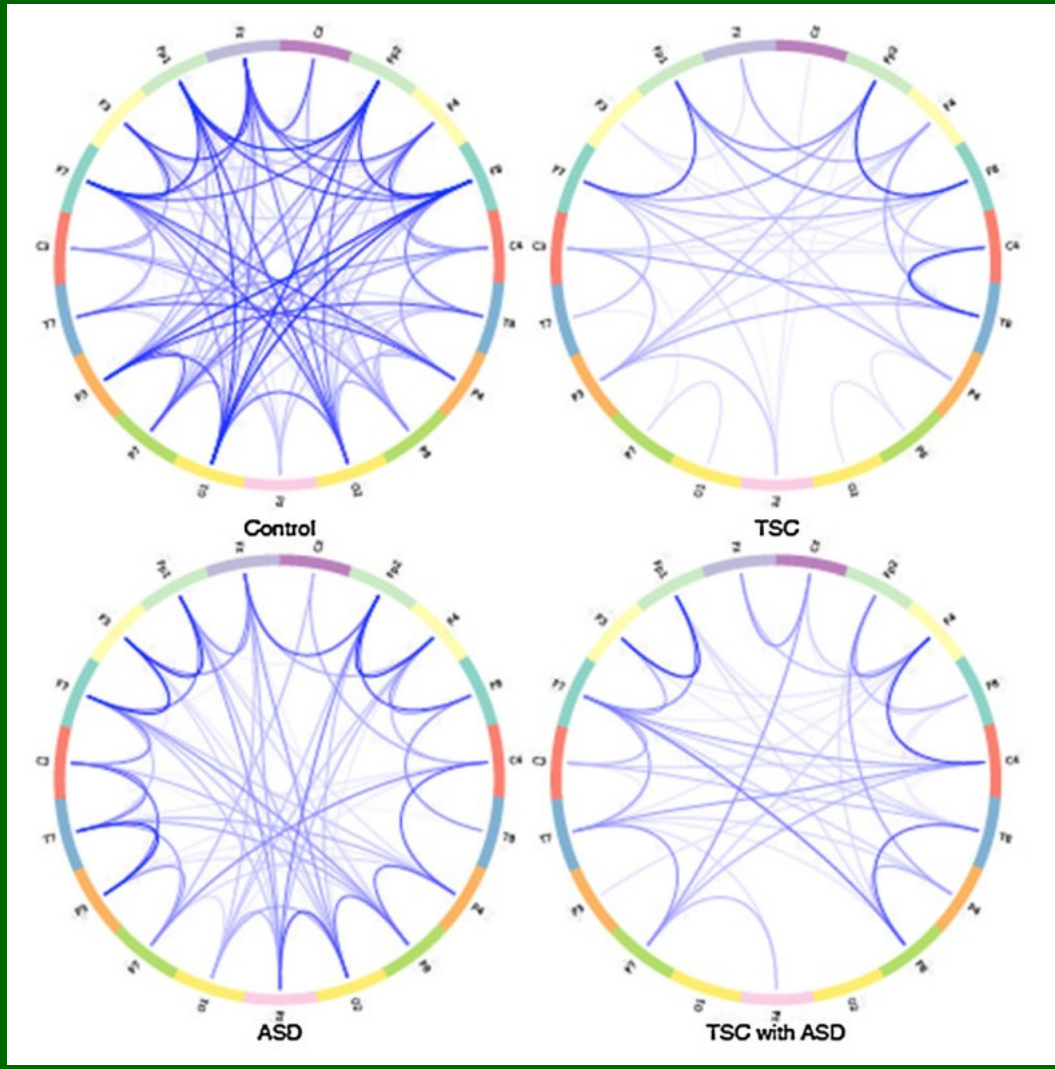
Closed loop system with brain stimulation for self-regulation.
Body may be replaced by sensory signals in Virtual Reality.

ASD: pathological connections

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

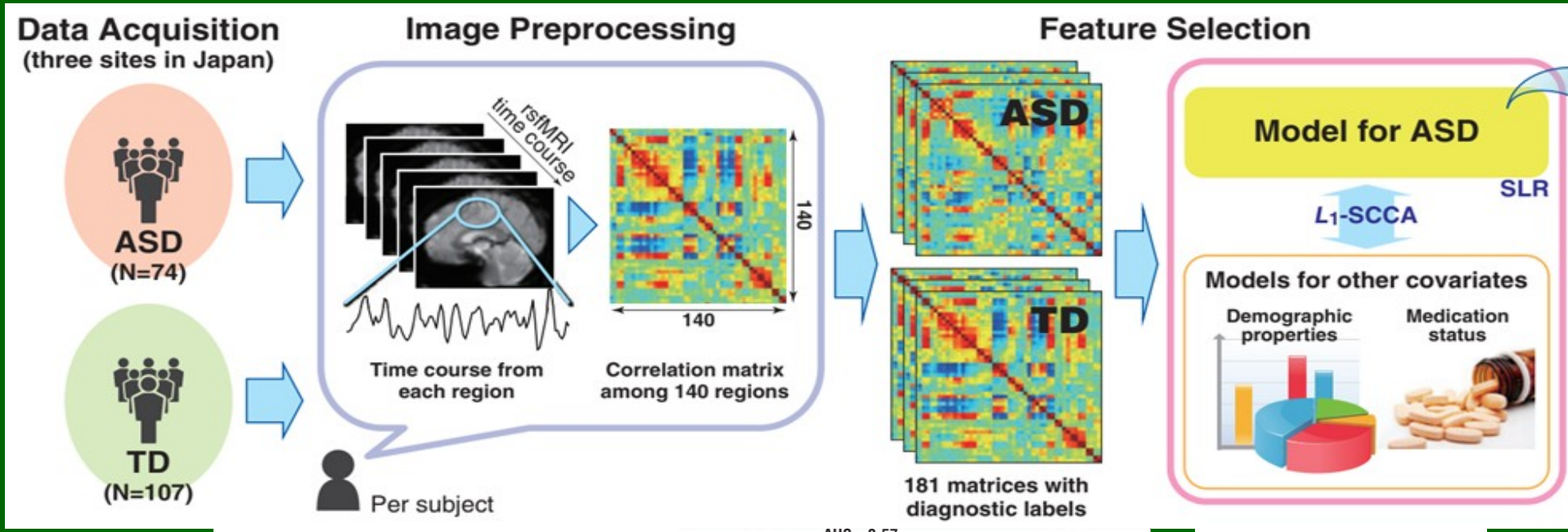
Coherence between electrodes. Weak or missing connections between distant regions prevent ASD/TSC patients from solving more demanding cognitive tasks.

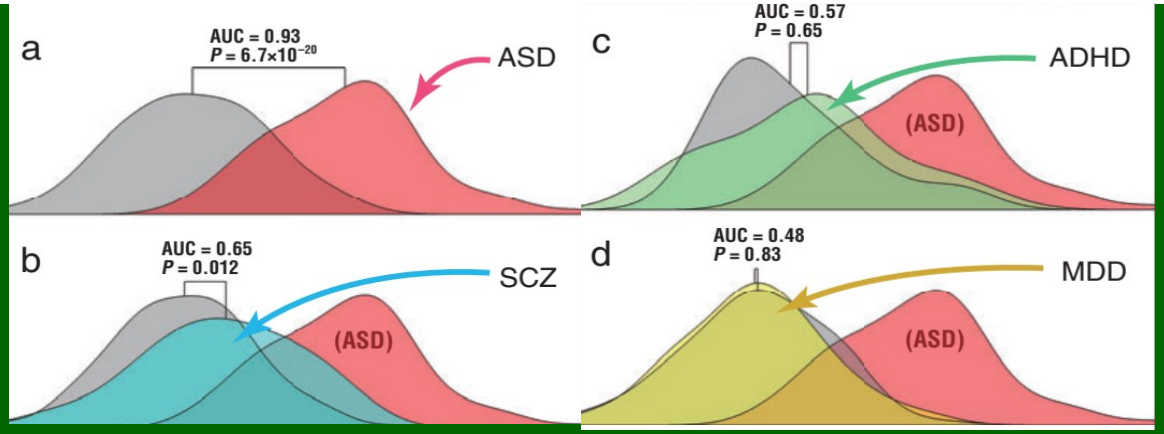
Network analysis becomes very useful for diagnosis of changes due to the disease and learning; **correct your networks**!

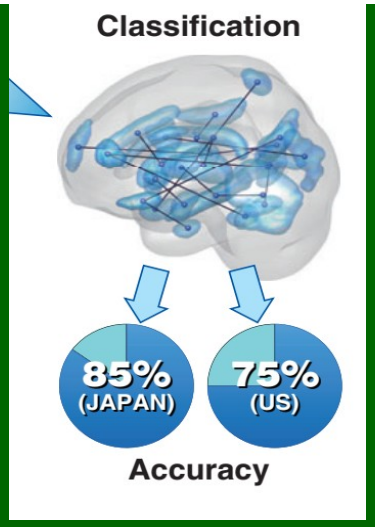


J.F. Glazebrook, R. Wallace, Pathologies in functional connectivity, feedback control and robustness. Cogn Process (2015) 16:1–16

Biomarkers from neuroimaging

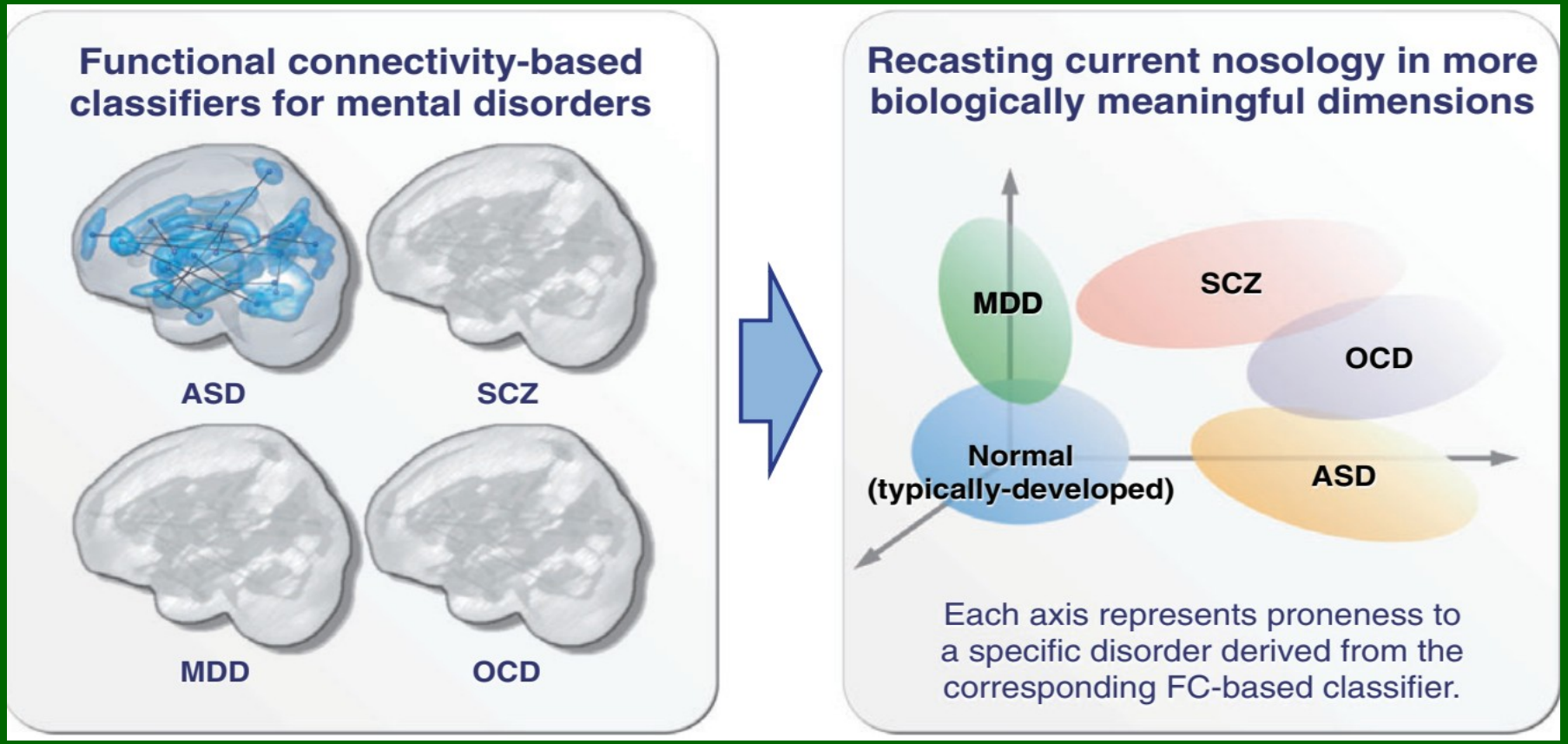






N. Yahata et al, *Psychiatry and Clinical Neurosciences* 2017: **71**

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

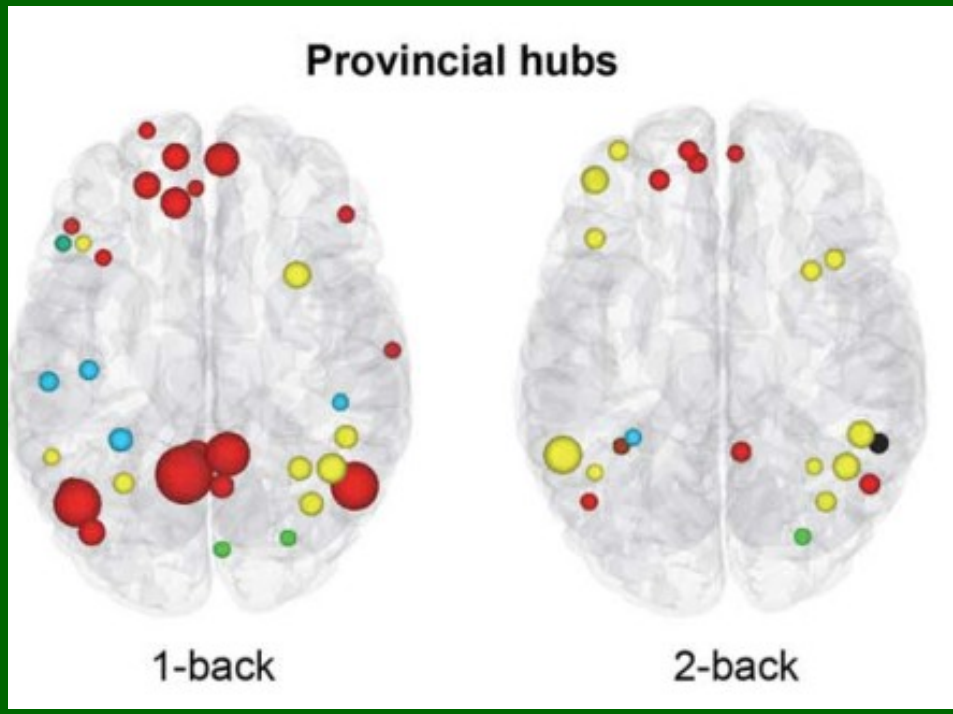
Simple and more difficult tasks, requiring the whole-brain network reorganization.

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

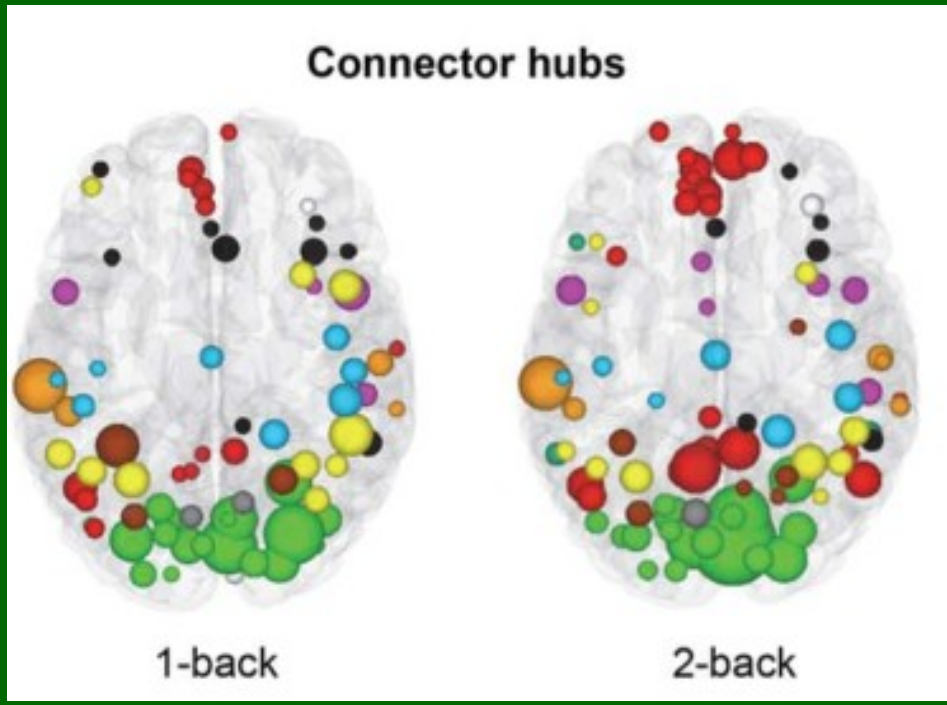
If the problem is hard recruit more brain regions to solve it! Functional synchronization unifies them.

Left: 1-back connector hubs

Right: 2-back connector hubs

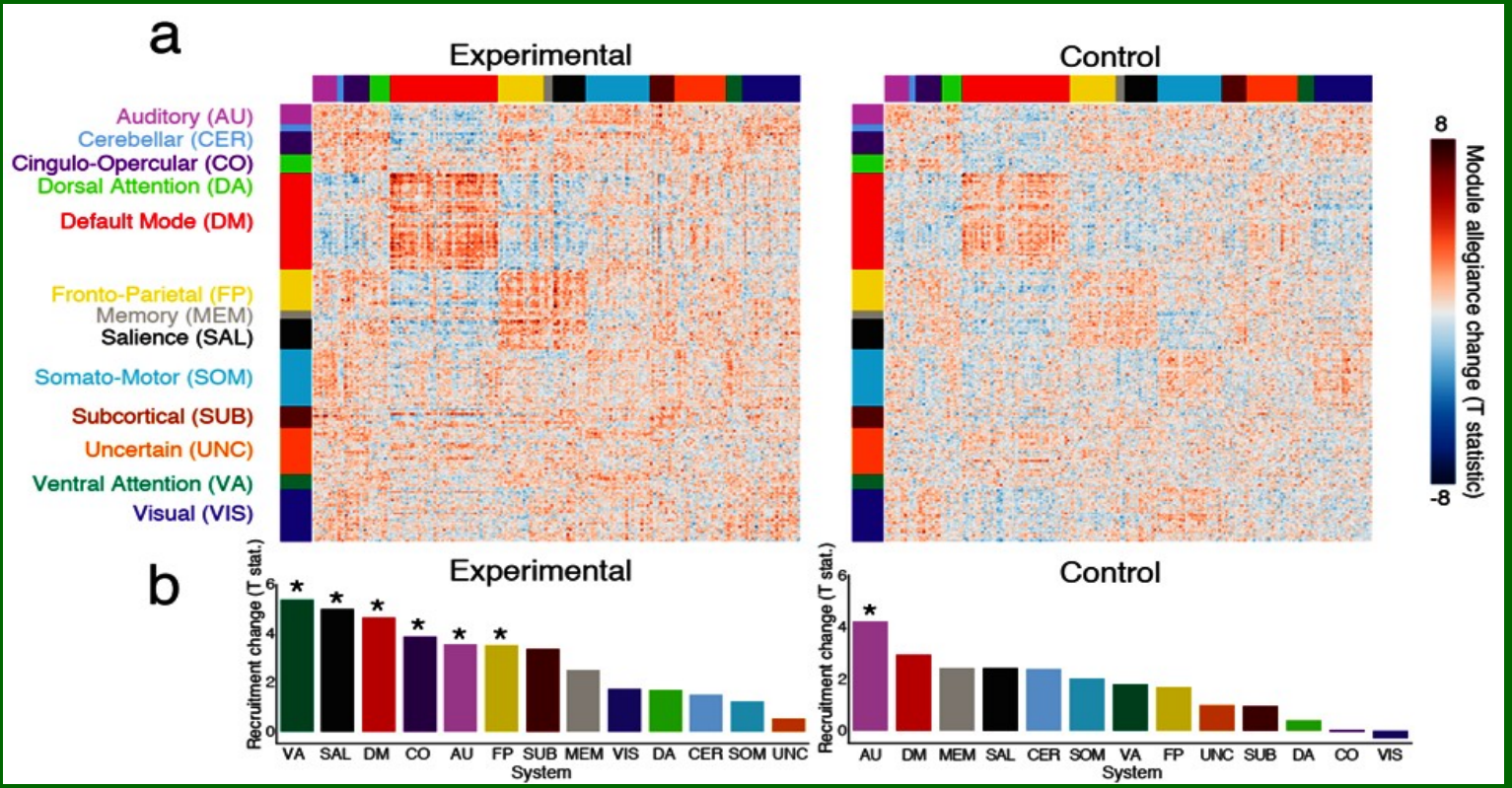
Average over 35 *participants.*

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).


episodic
autobiographical
procedural
working
priming
semantic
declarative
amnesia/disorders
STM/LTM
Vision
Audition
iconic
Somatosensory
Balance
implicit
Gustatory
Memory
Vigilance
Olfaction
Senses
Orientation
Imagery
Attention
Intentional
Personality
Self-consciousness
Learning
Awareness
Perception
Striatum
Amygdala
Mind
Consciousness
Disorders
Hypothalamus
Hippocampus
Thalamus
Homeostasis
Basal ganglia
Limbic System
Movement
Spinal Cord
Brian stem
Reticular formation
Control/WM
Nucleus accumbens
Frontal
Brain
Large Functional Networks
DMN
Planning
Prefrontal
VIS/AU
Neocortex/Lobes
Cortex gyri/sulci
Cerebellum
Multimodal
Insula
DAN/VAN/SN
Brain hemispheres
Corpus callosum
Signals
fMRI
Self
Limbic
Occipital
Neuromodulation
MEG
NIRS/HEG/MSOT
Vision
Emotions
Temporal
Parietal
TMS
tDCS
PET/SPECT
Language
Orientation
EEG/ERP/ECoG

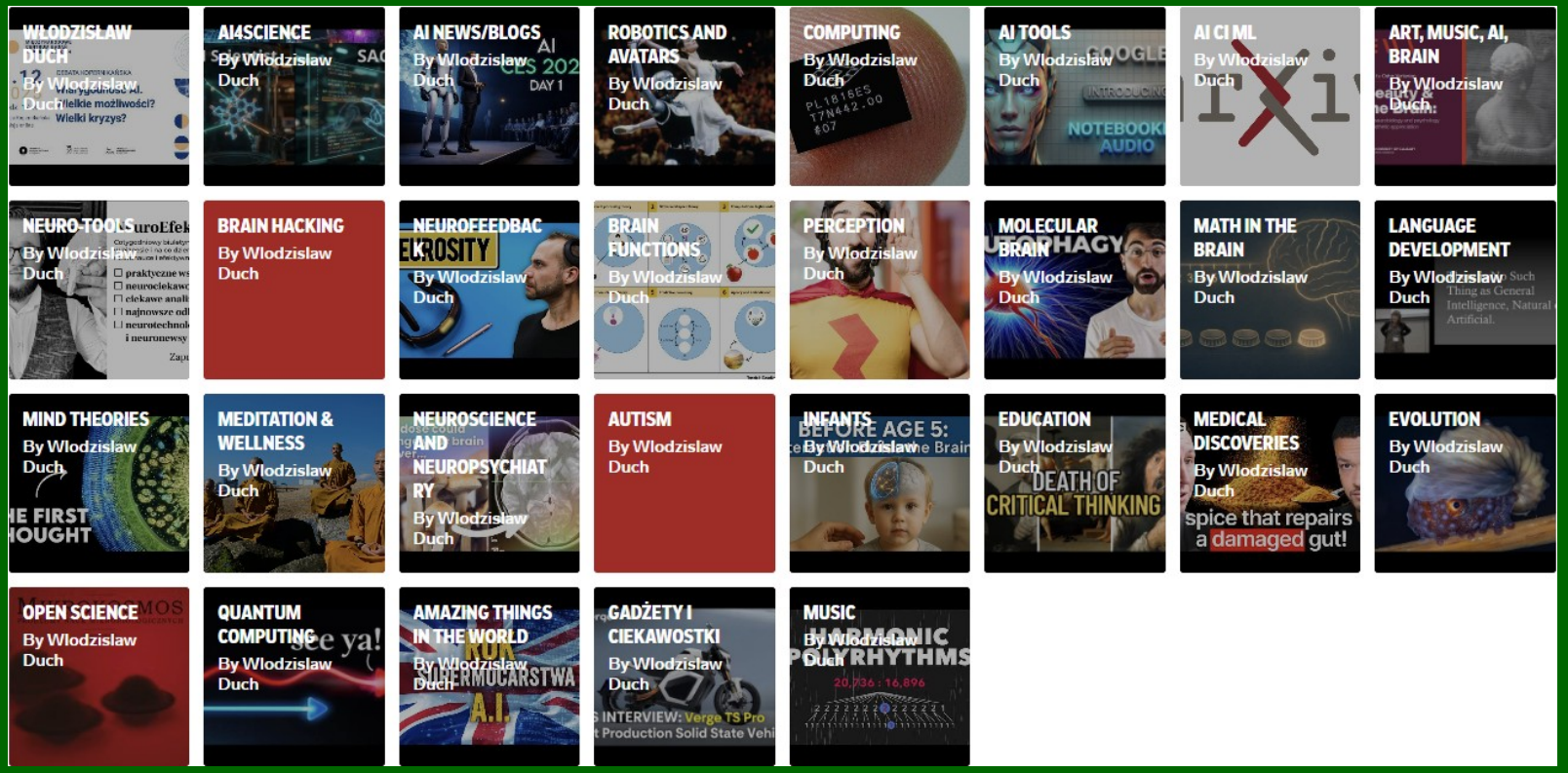
And in the end ...

More on brains, AI, artificial consciousness and many other topics.

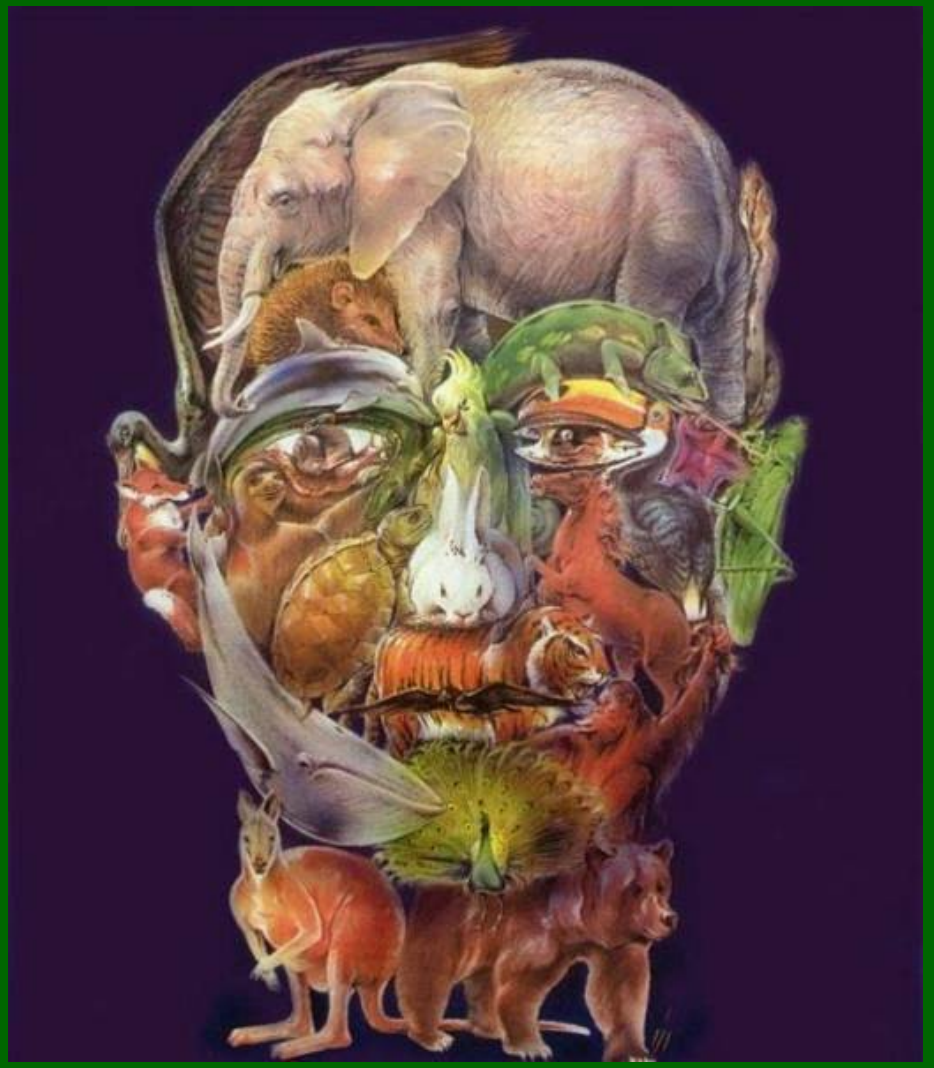
https://www.is.umk.pl/~duch/ref.html

Talks on YouTube

News on Flipboard



Thank you for stretching your imagination



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