Communication as a resonance between cognitive systems

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What will it be about

Cognitive Info-communication: how to pass information in an effective way to a cognitive system?

1. Information measures.
2. Concepts in the brain.
3. Visualizing brain activity.
4. Visualizing simulated neurodynamics.
5. Memes and conspiracies.
6. Communication as resonance between brains.

Center of Modern Interdisciplinary Technologies

Why am I interested in this?

Bio + Neuro + Cog Sci + Physics =>

NeuroCognitive Lab.

Other labs: molecular biology, chemical analytics, nanotech and electronics.

Main theme: maximizing human potential.

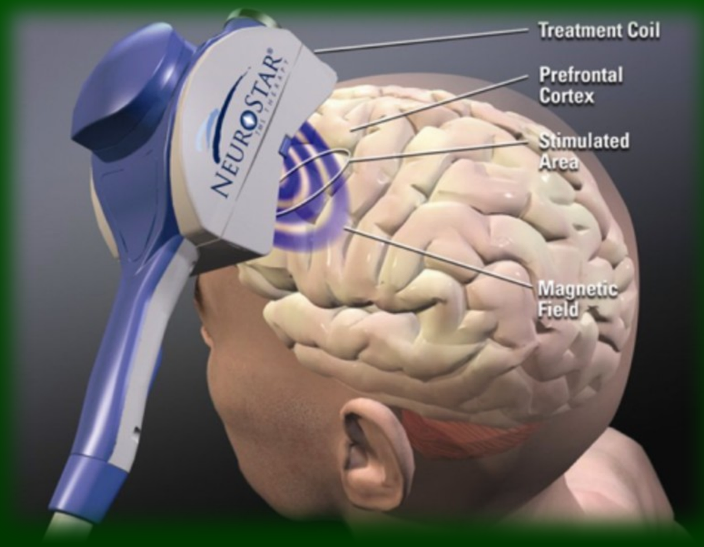
Goal: understanding brain-mind relations, with a lot of help from computational modeling and neuroimaging; pushing the limits of brain plasticity.

Big challenge! Funding: national/EU grants.

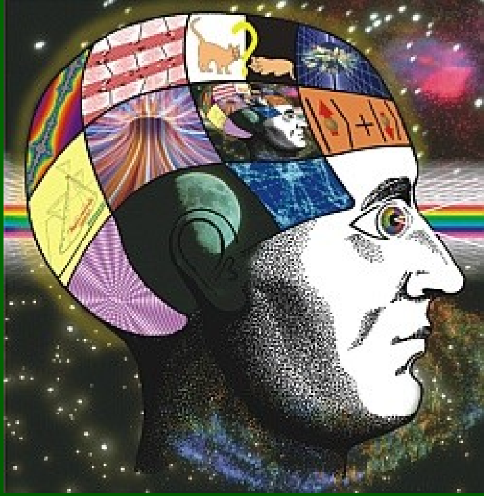
A group of neurofanatics

Our toys


personal genome machine


Treatment Coil
Prefrontal Cortex
Stimulated Area
Magnetic Field
NEUROSTAR

The problem



How do brains, using massively parallel computations, represent knowledge and communicate?

- **L. Boltzmann** (1899): “All our ideas and concepts are only internal pictures or if spoken, combinations of sounds.” „The task of theory consists in constructing an image of the external world that exists purely internally …”.
- **L. Wittgenstein** (Tractatus 1922): thoughts are pictures of how things are in the world, propositions point to pictures.
- **P. Johnson-Laird** (1983): mental models are psychological representations of real, hypothetical or imaginary situations.
- **J. Piaget**: humans develop a context-free deductive reasoning scheme at the level of elementary First-Order Logic.

Pictures? Logic? Both? What really happens in the brain?
How can we measure cognitive information?

Classical information

Information=average amount of surprise of observing X (data, signal, object).

1. If P(X)=1 there is no surprise, so s(X)=0
2. If P(X)=0 then this is a big surprise, so s(X)=∞.
3. If observation of X is independent of Y than P(X,Y) = P(X)P(Y).

   Assumption: surprise is additive s(X,Y) = s(X)+s(Y).

The only suitable surprise function that fulfills these requirements is ...

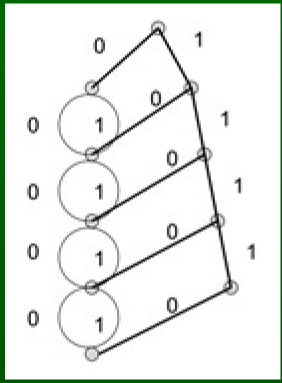
$$s(X) = \lg \frac{1}{P(X)} = -\lg P(X)$$

Information= average amount of surprise, change in disorder (entropy):

$$H(X) = E\left[\lg \frac{1}{P(X)}\right] = -\sum_{i=1}^{n} P\left(X^{(i)}\right) \lg P\left(X^{(i)}\right) \geq 0$$

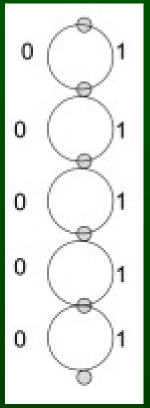
Cognitive Information

Shannon information is a surprise for system that has **no knowledge**.



How to define surprise for a cognitive system that has some knowledge? New information changes its structure.
Measure change in algorithmic information.

Ex: adding 11111 string will lead to a large restructuring of binary graph, removing 9 edges and 5 nodes, adding 2 edges.
Equivalent to compression/simplification of finite state automata rules.



Adding a new rule to knowledge base may restructure cognitive system.

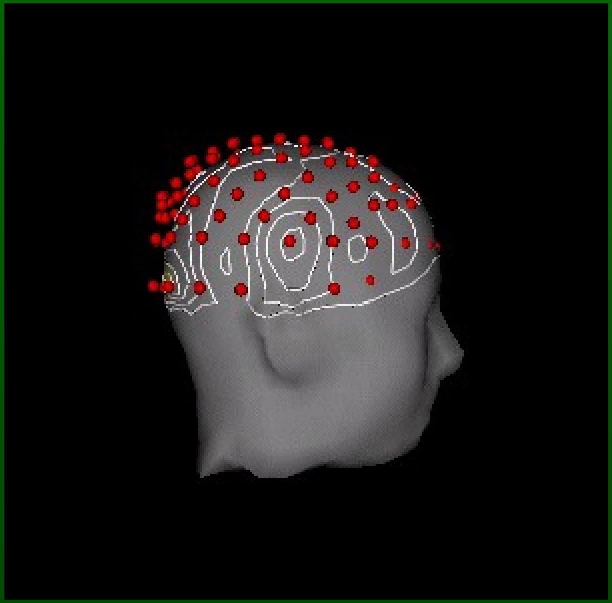
In general, given cognitive model *M* based on data *D* with complexity *M*(*D*) the value of new information *S* for this model is measured by:

$$I_M(S) = \left\| M(D+S) - M(D) \right\|$$

Many measures of complexity have been proposed (Bayesian measures for distributions, Minimum Description Length). In case of neural systems learning changes the structure of potentially accessible dynamical states.

Brains and computers

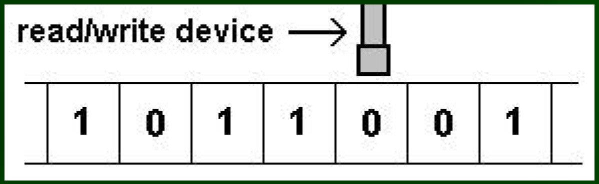
Brains: neurodynamics, continuously changing activation of the brain in space and time.



Computer registers: no space, time irrelevant, counting bits in central processors.

Brain state: distributed neurodynamics, each brain state partially contains in itself many associations, relations, other states.

Mind state: internal interpretation of active attractor states at a given moment.



Computers and robots are not based on processes equivalent to neurodynamics, interactions between attractor states.
Analog neurochips may form such dynamics.

W. Duch, J. Minds and Behavior 2005

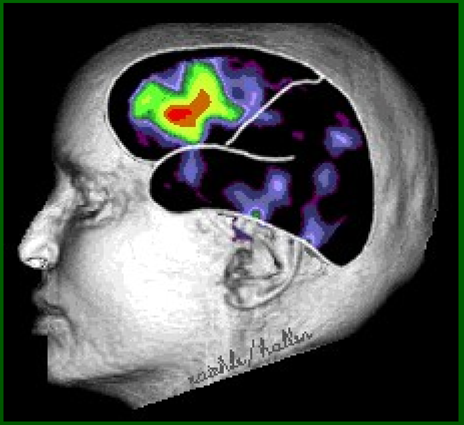
Geometric model of mind

Objective ⇔ Subjective.

Brain ⇔ Mind.

Neurodynamics describes state of the brain activation measured using EEG, MEG, NIRS-OT, PET, fMRI or other techniques.

Mind states=f(Brain states)

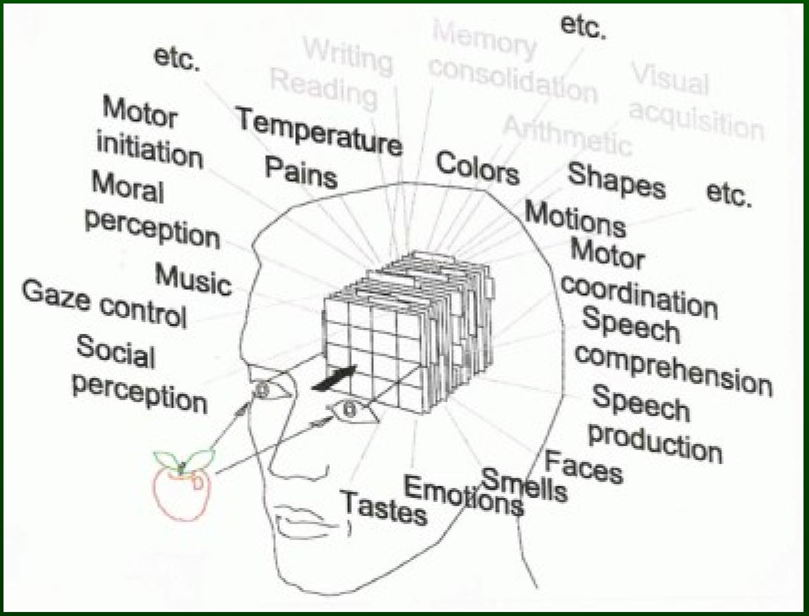


How to represent mind state?

In the space based on dimensions that have subjective interpretation: intentions, emotions, qualia.

Mind state and brain state trajectory should then be linked together by some transformations. Intentions are uncovered by the **Brain-Computer Interfaces.**

Lack of neurophenomenology, but

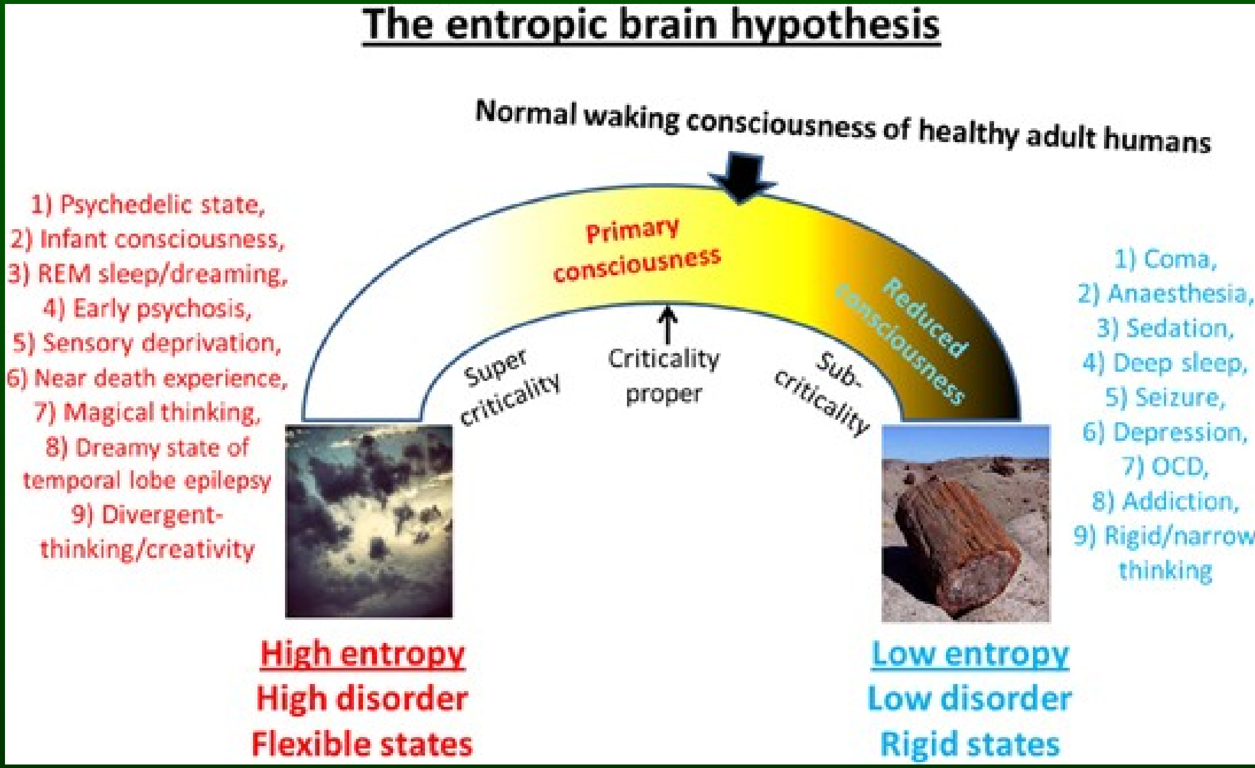


Measuring consciousness

How to quantitatively measure the level of consciousness in people during anesthesia, epilepsy, coma, disordered states of consciousness, in infants, various animals and machines?

Complexity of neurodynamics: not too chaotic, not too regular.

Several attractor states linking many brain areas, medium entropy.

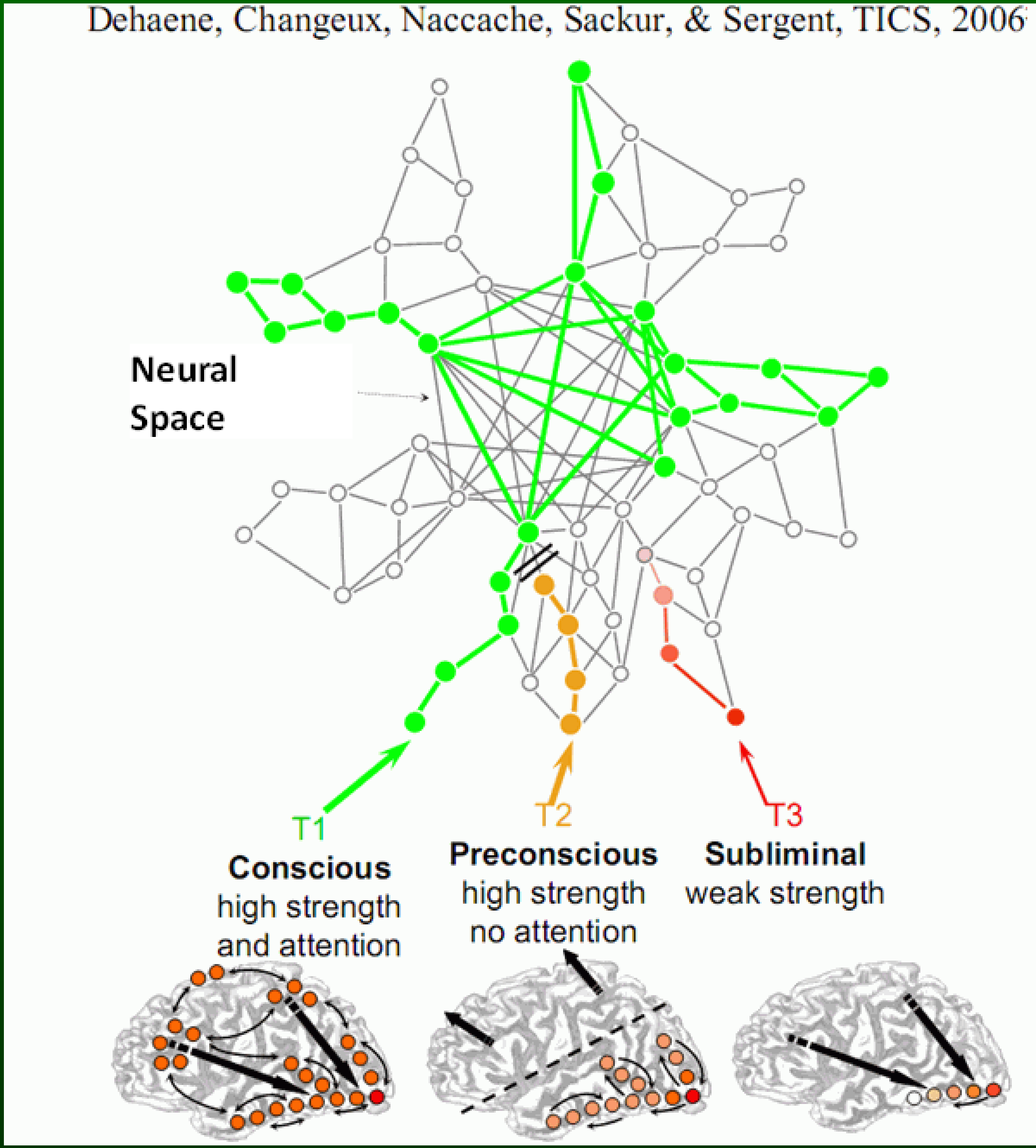


Conscious Perception

Very little of what passes in the brain is perceived.

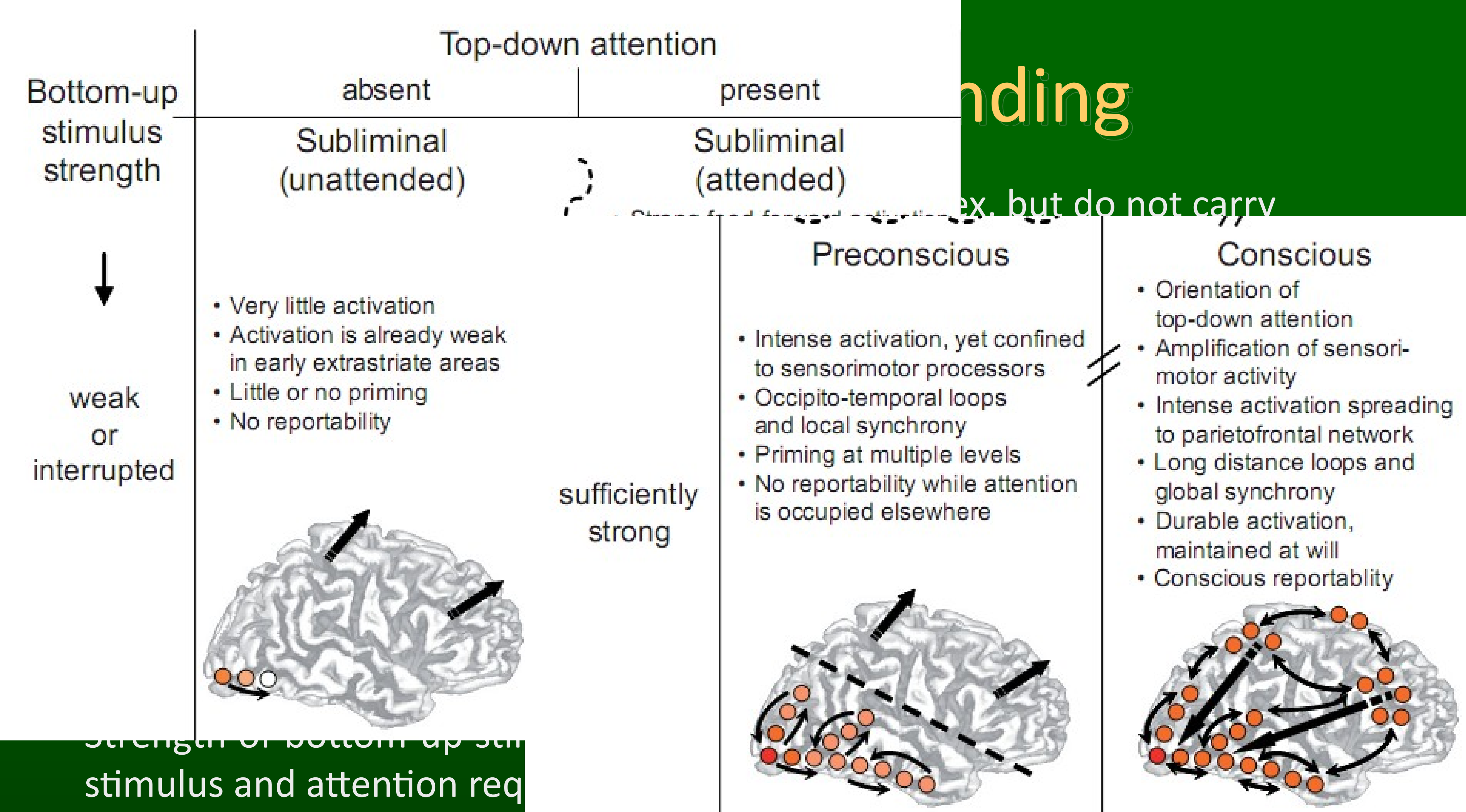
Attention + stimulation is needed to create brain states that are persistent and can be distinguished from noise.
Attention: 20 Hz
Perception: 40 Hz

C. Gilbert, M. Sigman, Brain States: Top-Down Influences in Sensory Processing. Neuron 54(5), 677-696, 2007



…nding

…ex, but do not carry

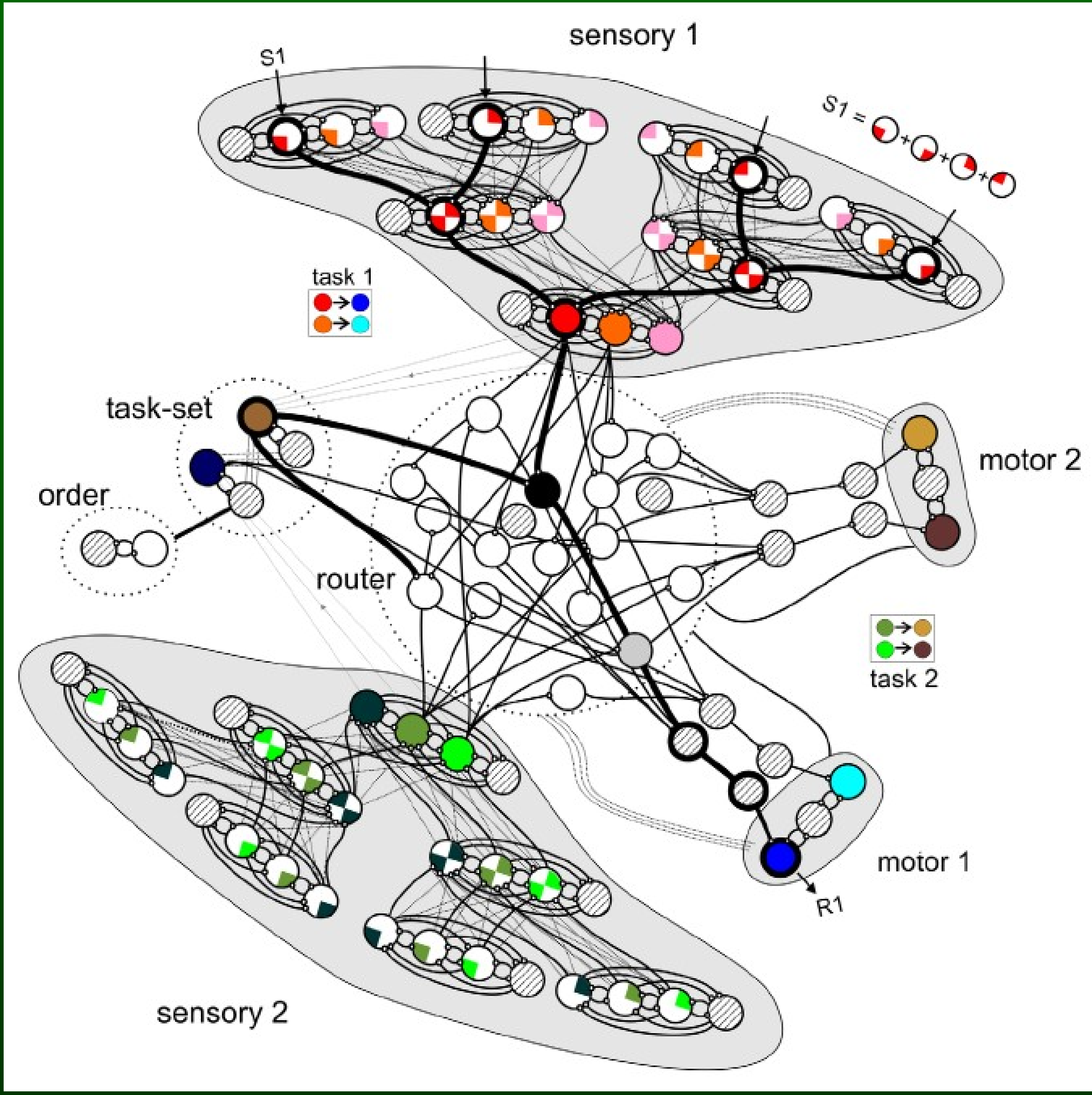


stimulus and attention req…

C. Gilbert, M. Sigman, Brain States: Top-Down Influences in Sensory Processing. Neuron 54(5), 677-696, 2007

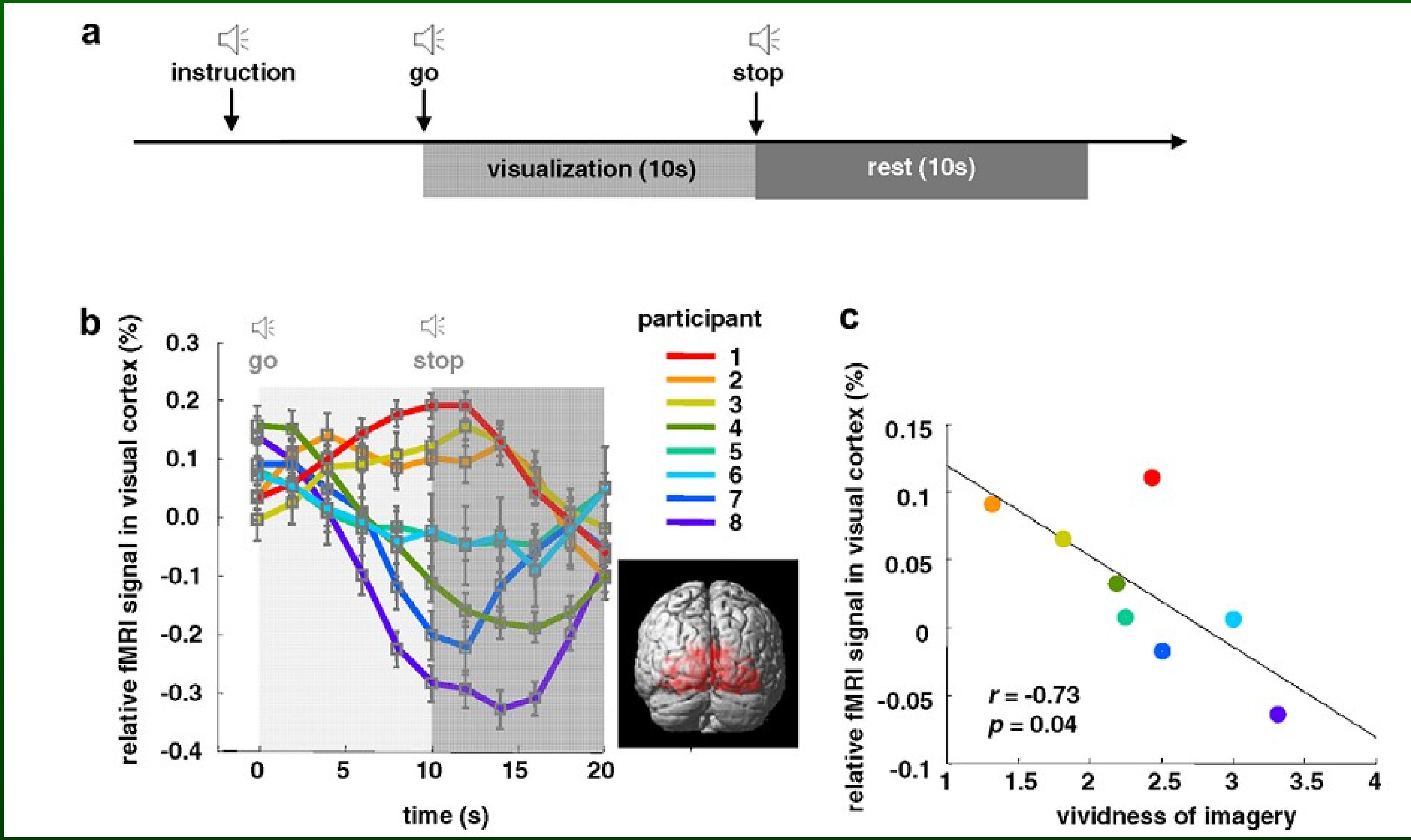
S. Dehaene et al, Conscious, preconscious, and subliminal processing, TCS 2006

Spiking neuron model of sensory, central and motor processes. Parallel processing at peripheral sensory levels, a memory buffer, slow serial performance at the router stage, resulting in a performance bottleneck. The model captures detailed dynamics of dual-task-performance, RTs and their distribution, in experiments with humans and non-human primates.
A. Zylberger, PLOS Biology 2010



Neural canvas

Content of conscious perception is expressed in the whole brain.

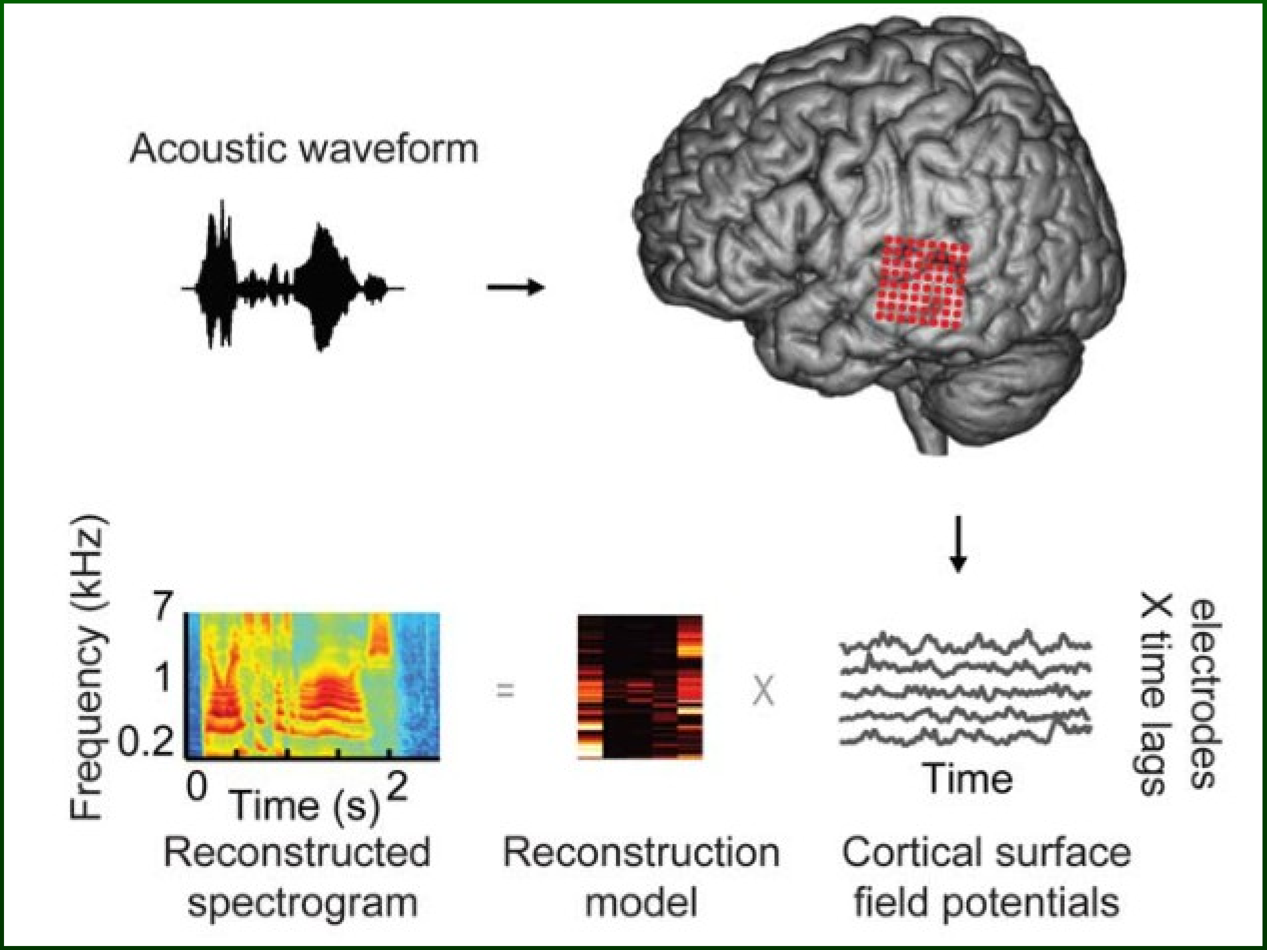


Results of the Vividness of Visual Imagination (VVIQ) questionnaires and V1 activity measured by fMRI are strongly correlated: some details are in V1.
Cui, X et al. Vision Research, 47, 474-478, 2007

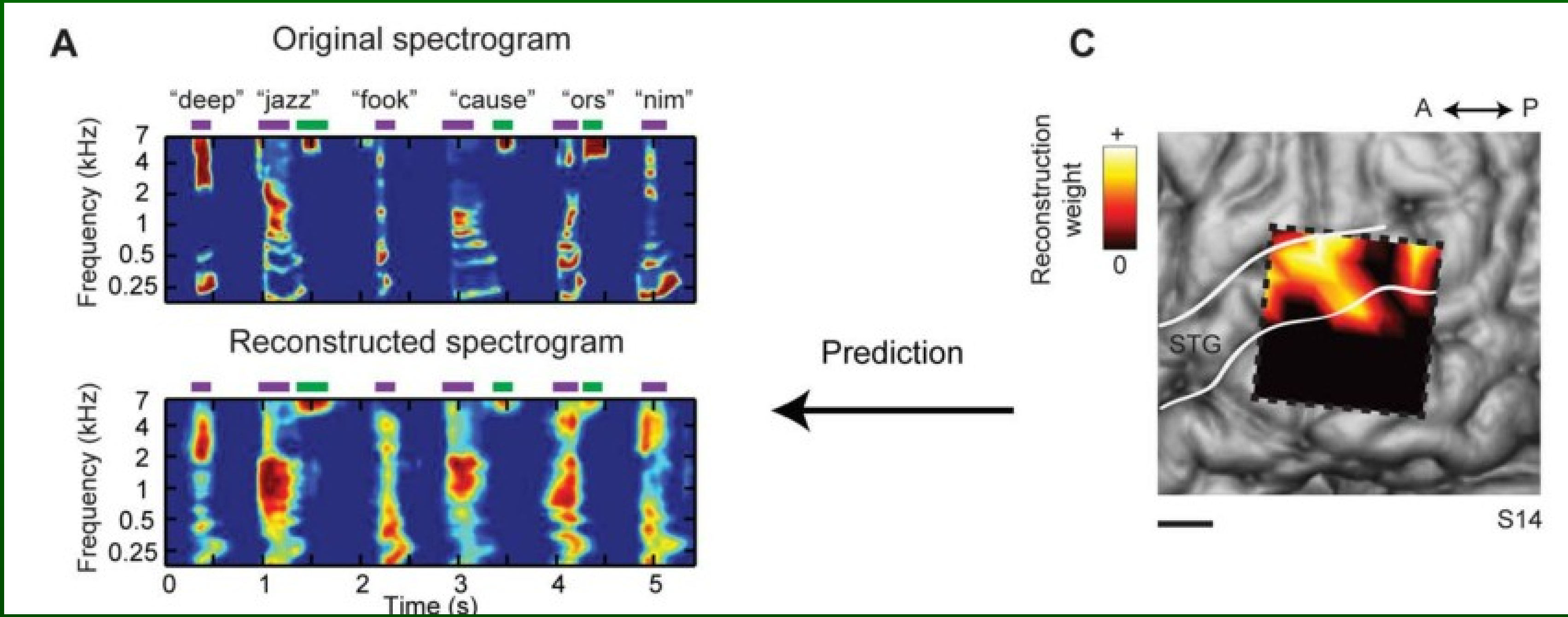
Sound in the brain

A mesh of electrodes measuring cortical electric field potentials allows for reconstruction of speech from measured brain activity.

We can see the sounds in the brain and recreate them from neural impulses.



Time, place, energy, frequency



All brain activity is just trains of neural impulses and microcircuit activations. Neural representation of sound can be analyzed by a 4-dimensional spectrograms of the auditory cortex activity.

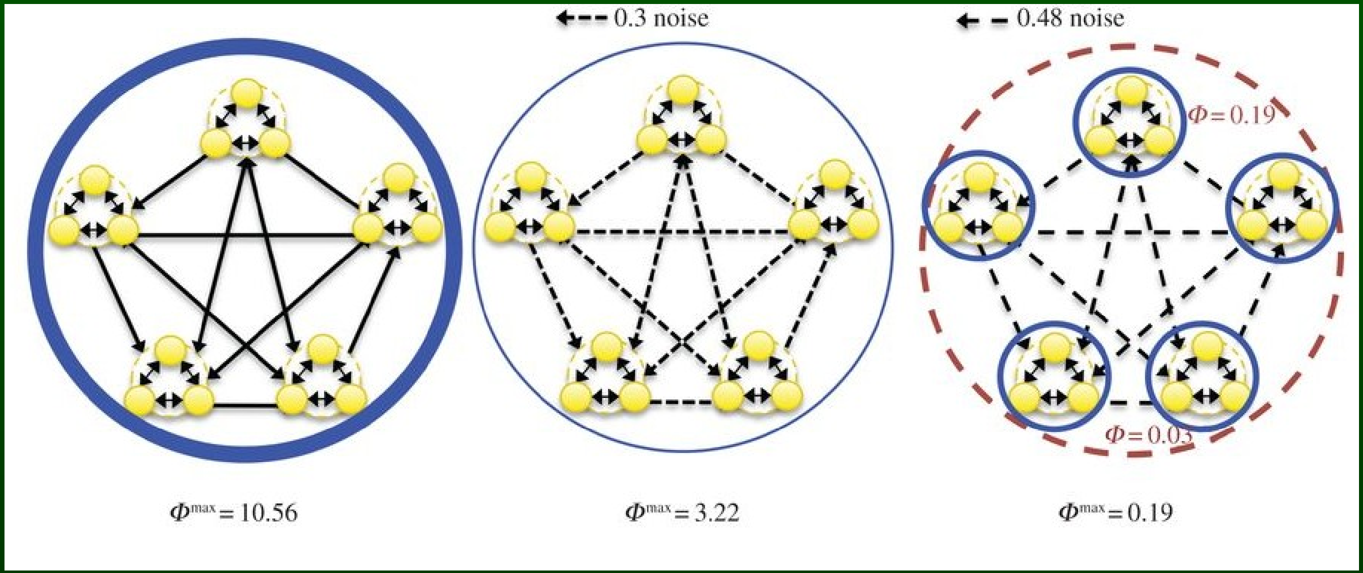
Pasley et al. Reconstructing Speech from Human Auditory Cortex. PLOS Biology 2012.

Integrated Information Theory

Information integration theory of consciousness (IITC, Tononi, Edelman, Science 1998) defines *integrated information* (Φ) generated by the neural system, balancing global integration and local information richness.

Seth (2011) proposed causal density measure, calculated as the fraction of interactions among neural groups that are casually significant.

Quantity (strength) and quality (shape) of experience is defined by the conceptual structure that is maximally irreducible intrinsically.



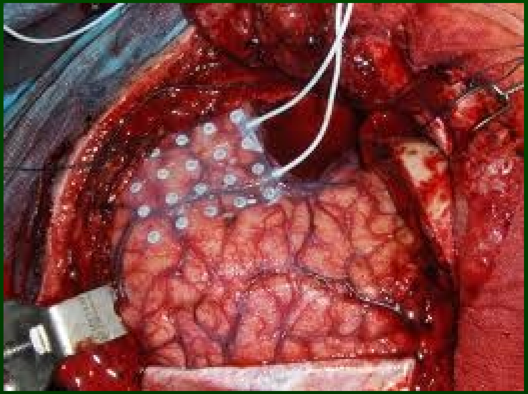
Tononi G, Koch C. (2015) Consciousness: Here, there and everywhere? Phil. Trans. Royal Society

Brain-computer interfaces

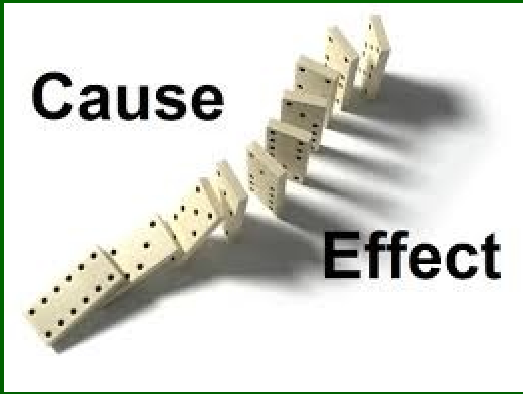
Mind reading is an exciting and rapidly developing field.
Brain-computer interfaces (BCI) read and interpret some activity of the brain.
Conscious, intentional activity is detected.

BCI development is motivated by the desire to communicate with people in locked-in or minimal consciousness states (and games -;).

Can we measure consciousness looking at information processing in the brain?
Can we communicate creating resonance states coupling human-robot brains?



IIT postulates



The IIT is based on 5 general postulates, expressed in a general form below. They may be translated to properties of attractor networks in brain-inspired cognitive architectures (BICA).

1. **Intrinsic existence**: must have cause–effect power upon itself.
2. **Structured subsets** of the elementary mechanisms of the system, composed in various combinations, also have cause–effect power.
3. Information in the cause–effect repertoires is specified by each composition of elements within a system.
4. **The cause–effect structure** specified by the system must be unified: it must be intrinsically irreducible, **a quale**.
5. The cause–effect structure specified by the system must be definite, specified over a single set of elements over which it is maximally irreducible from its intrinsic perspective.

Basically: model of the environment,

IIT conclusions

Consciousness is a fundamental property of physical systems organized in brain-like way, having real cause–effect power, shaping the space of possible past and future states in intrinsically maximally irreducible way (Φ measure).

Quantity (strength) and quality (shape) of experience is defined by the conceptual structure that is maximally irreducible intrinsically: quality differs depending on configuration of elements involved.

Feedforward systems cannot be conscious, recurrence is needed.

Computer simulation of the brain will not create consciousness - activity of computer elements is not sufficiently integrated in a unified process, breaks down into many mini-complexes of low Φ^{max}.

However, Tononi and Koch do not mention neurocomputers based on massively parallel neurochips (as for ex. in the SYNAPSE project and TrueNorth neurochips).
According to IIT such systems could become conscious and it can be measured.

IIT and real brain processes

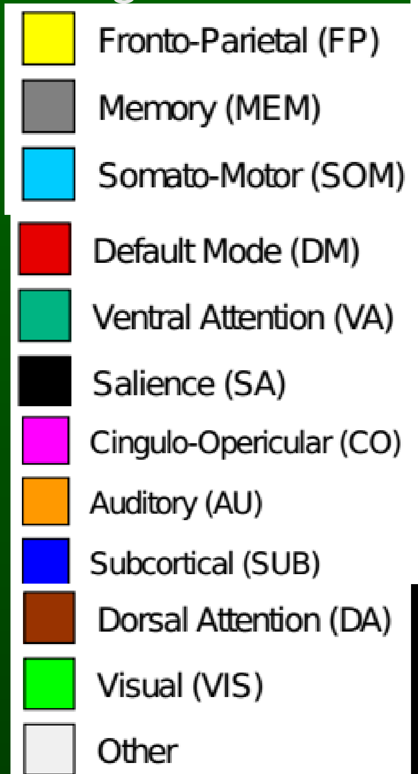
Simple and more difficult tasks, requiring the whole-brain network reorganization.

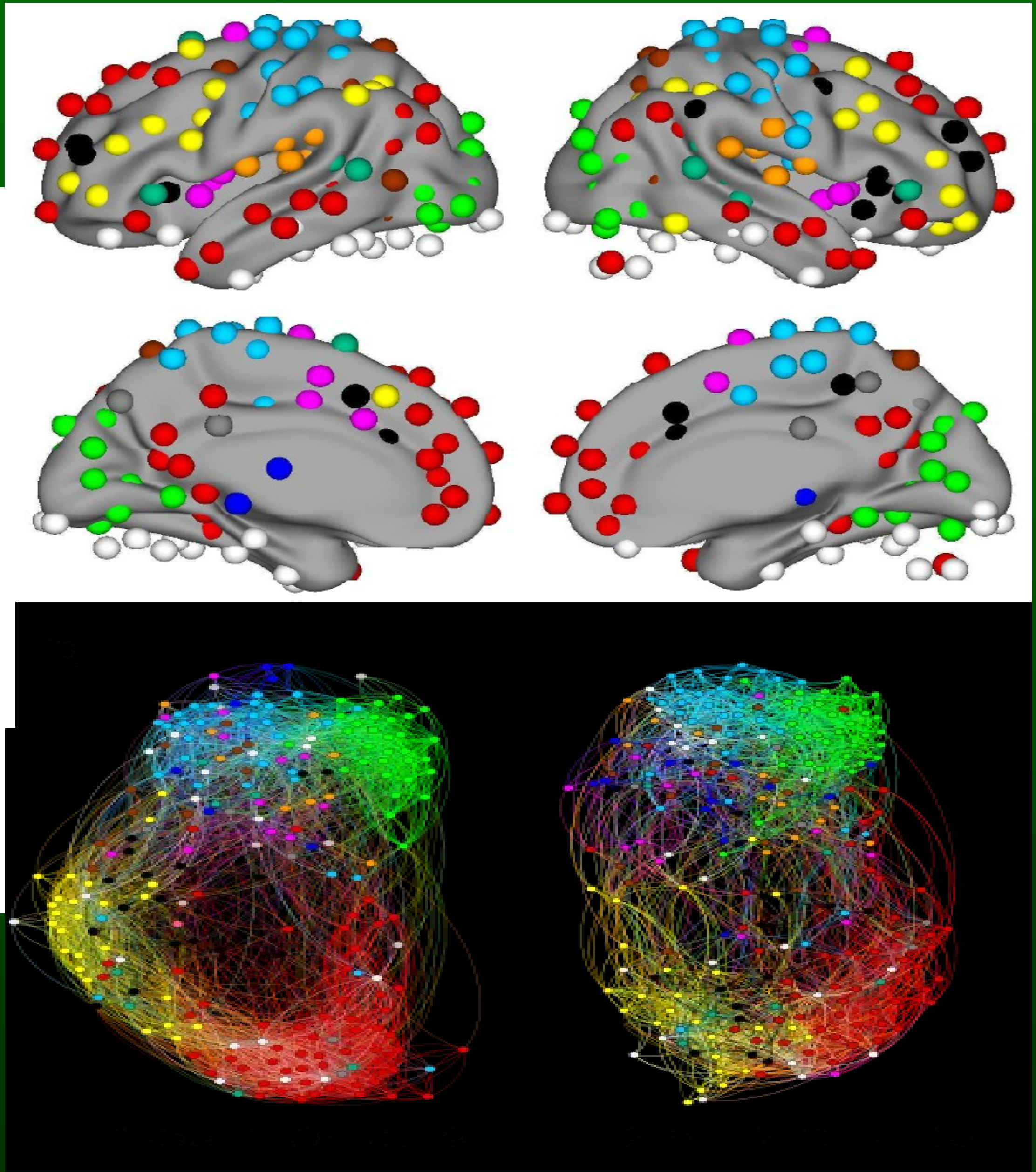
Left: 1-back

Right: 2-back

Left and midline sections.

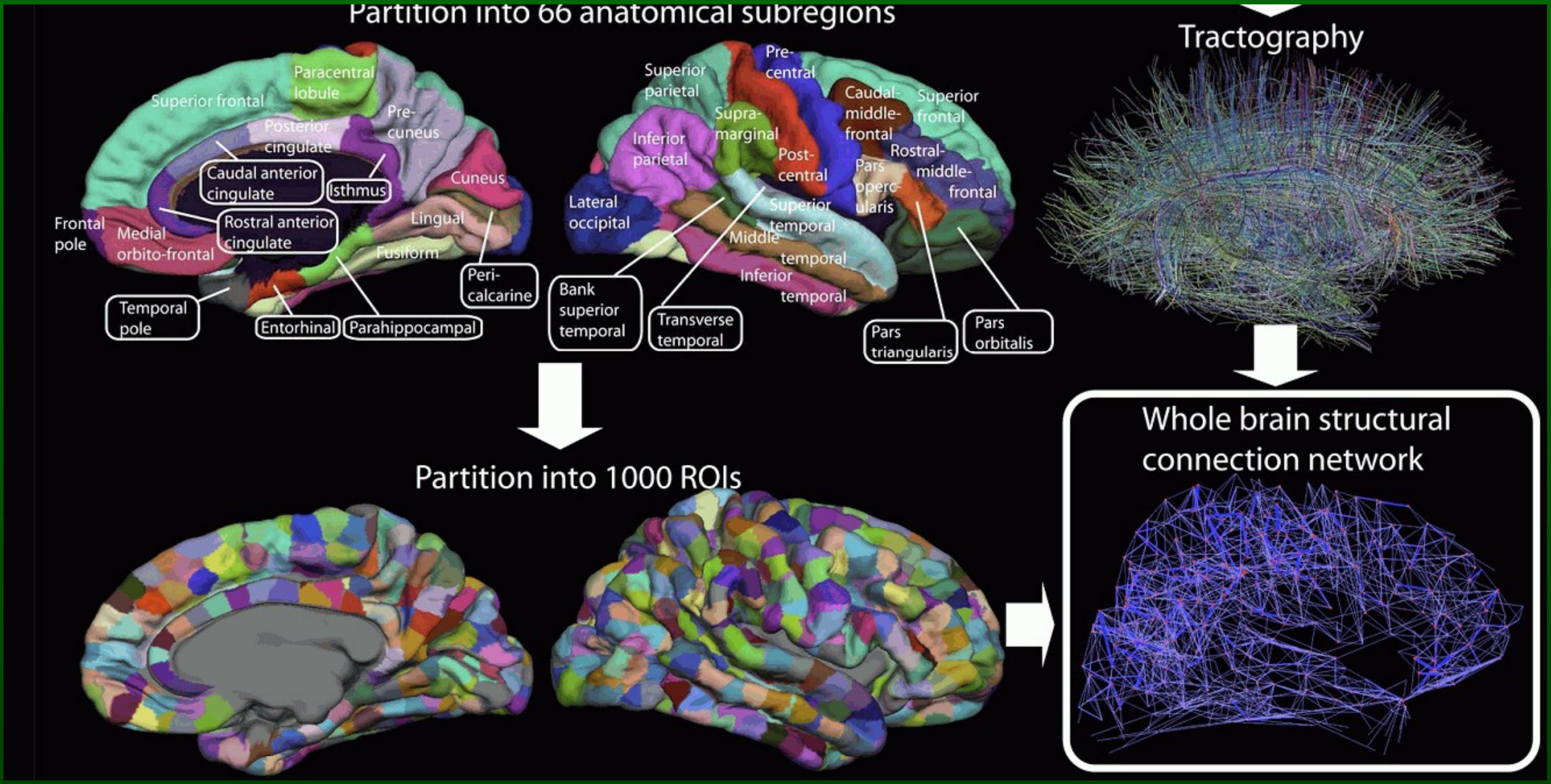
Average over 35 participants.





K. Finc et al (HBM, in rev, with World Hearing Center, MPI for Human Development).

Connectome

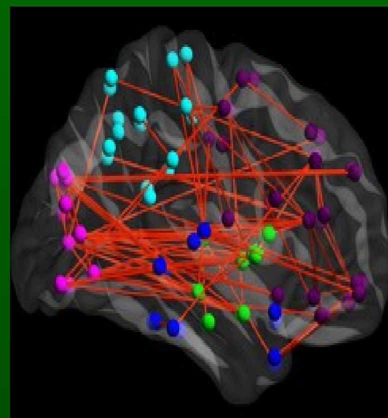


Connect 1000 regions of interest (ROI). Brain state are ROI activations.
Neural determinism: experience shapes functional brain connectivity.
New things are learned on the canvas of what we already know, the order in which we learn is important.

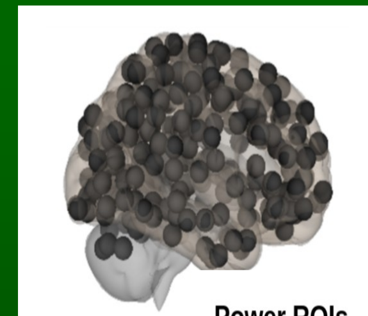
Human connectome and MRI/fMRI

Structural connectivity

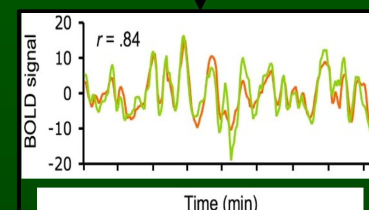
Functional connectivity



Node definition

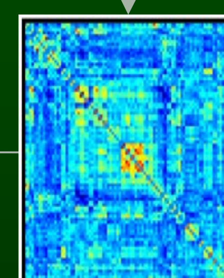


Signal extraction



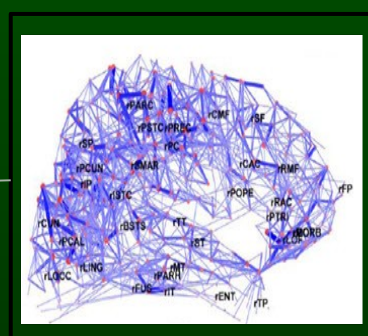
Correlation calculation

Correlation matrix

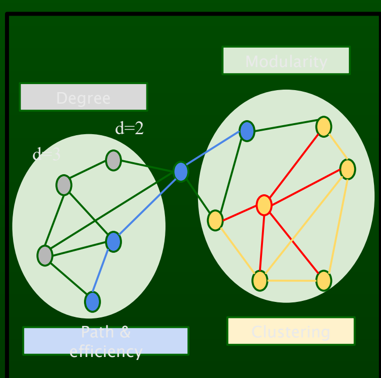


Binary matrix

Whole-brain graph

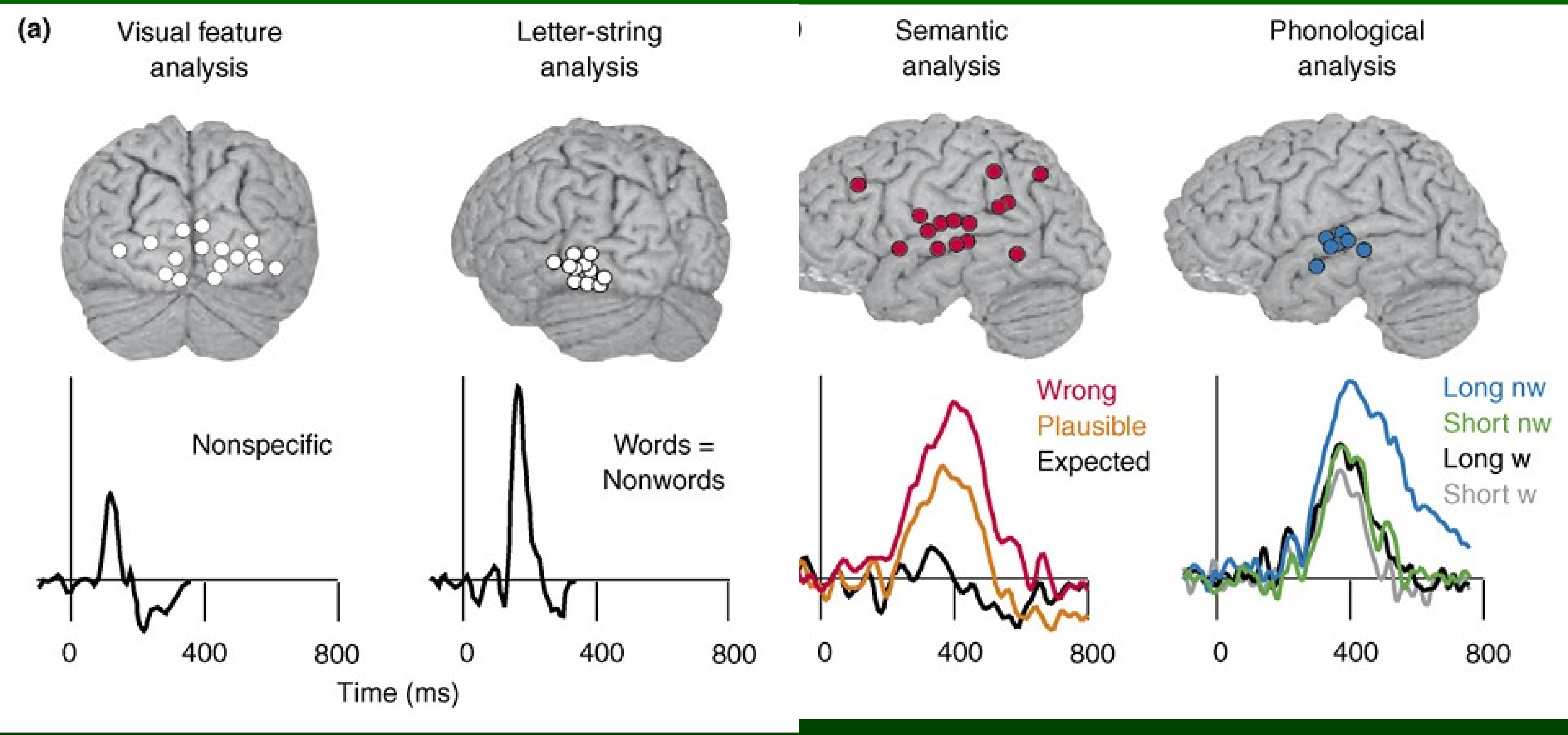


Graph theory



Bullmore & Sporns (2009)

Brain during reading

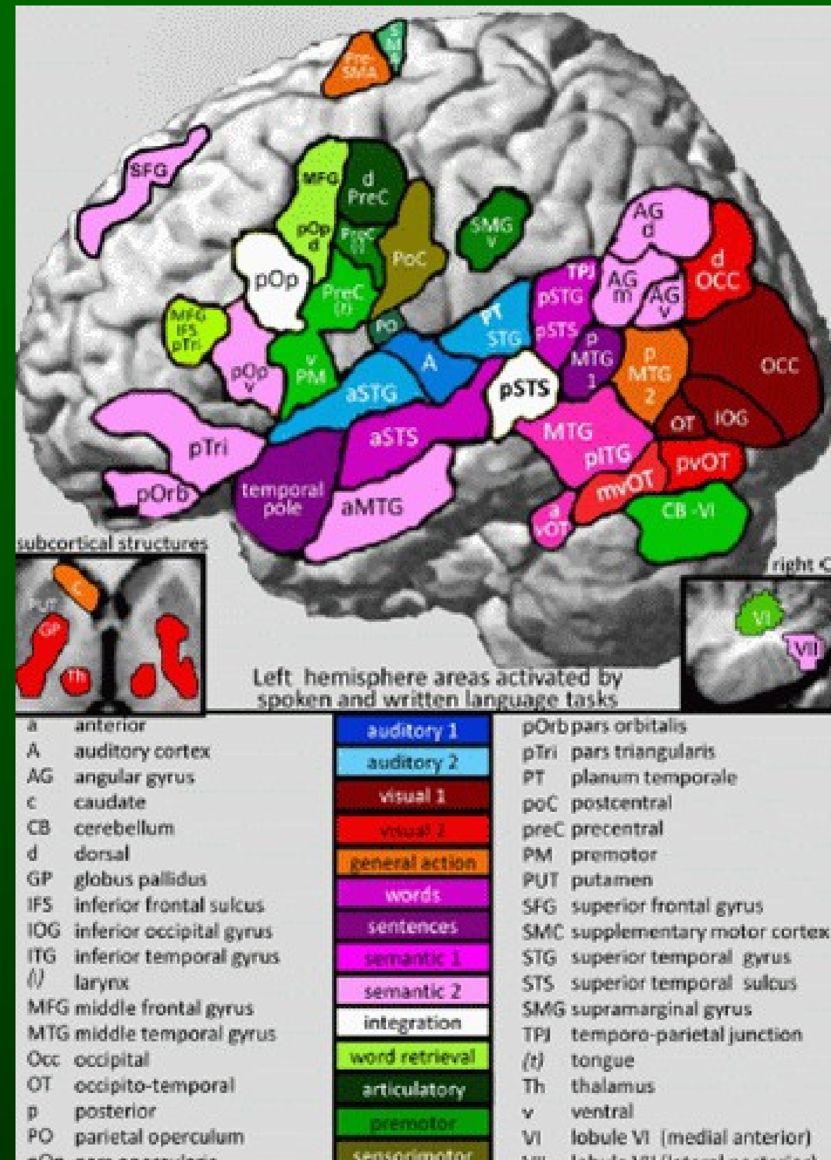


R. Salmelin, J. Kujala, Neural representation of language: activation versus long-range connectivity. TICS 10(11), 519-525, 2006 (MEG activity patches)

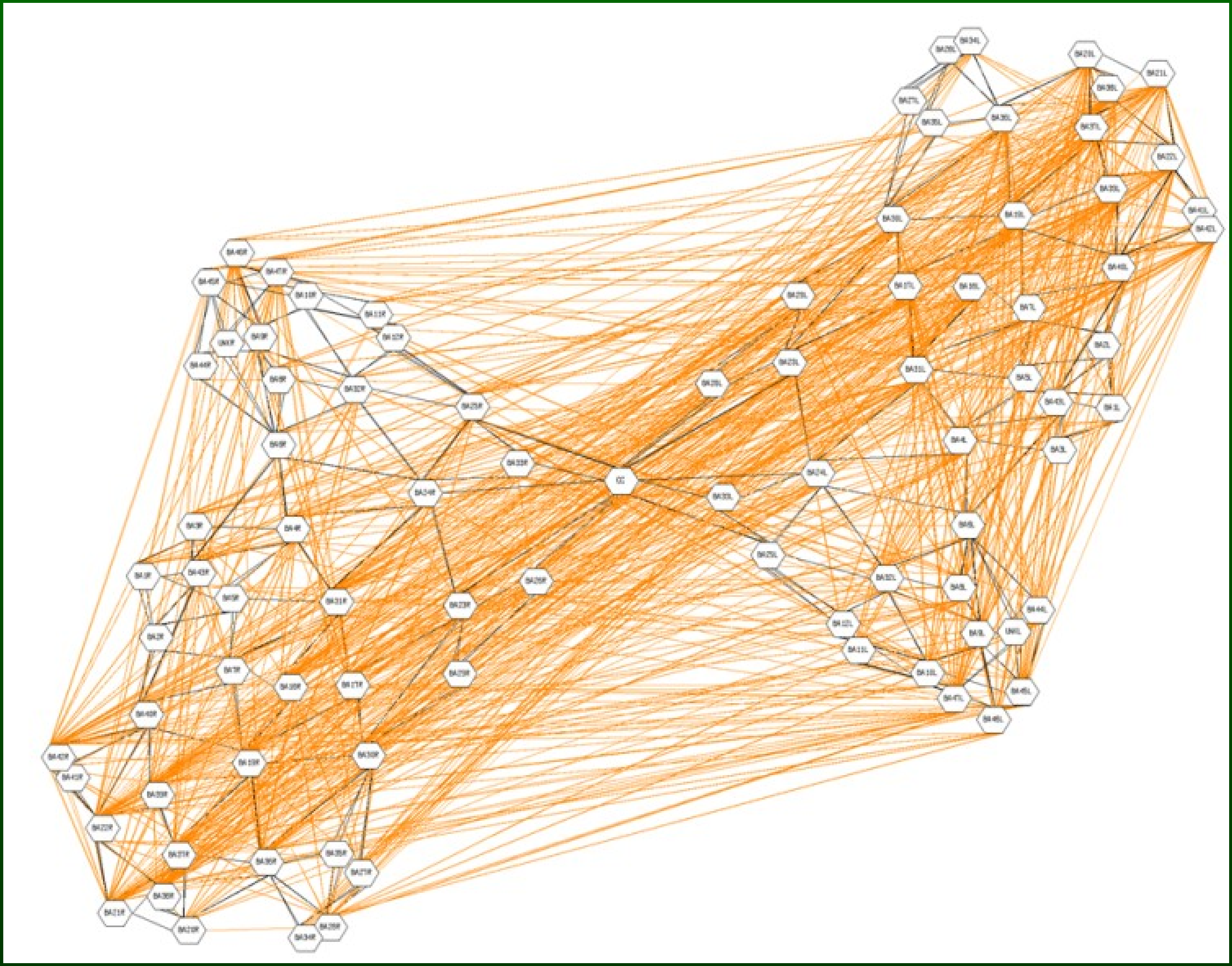
Language areas

Left hemisphere areas that are activated during reading or listing to speech.

Other areas are activated during thinking, making inferences, understanding metaphores.

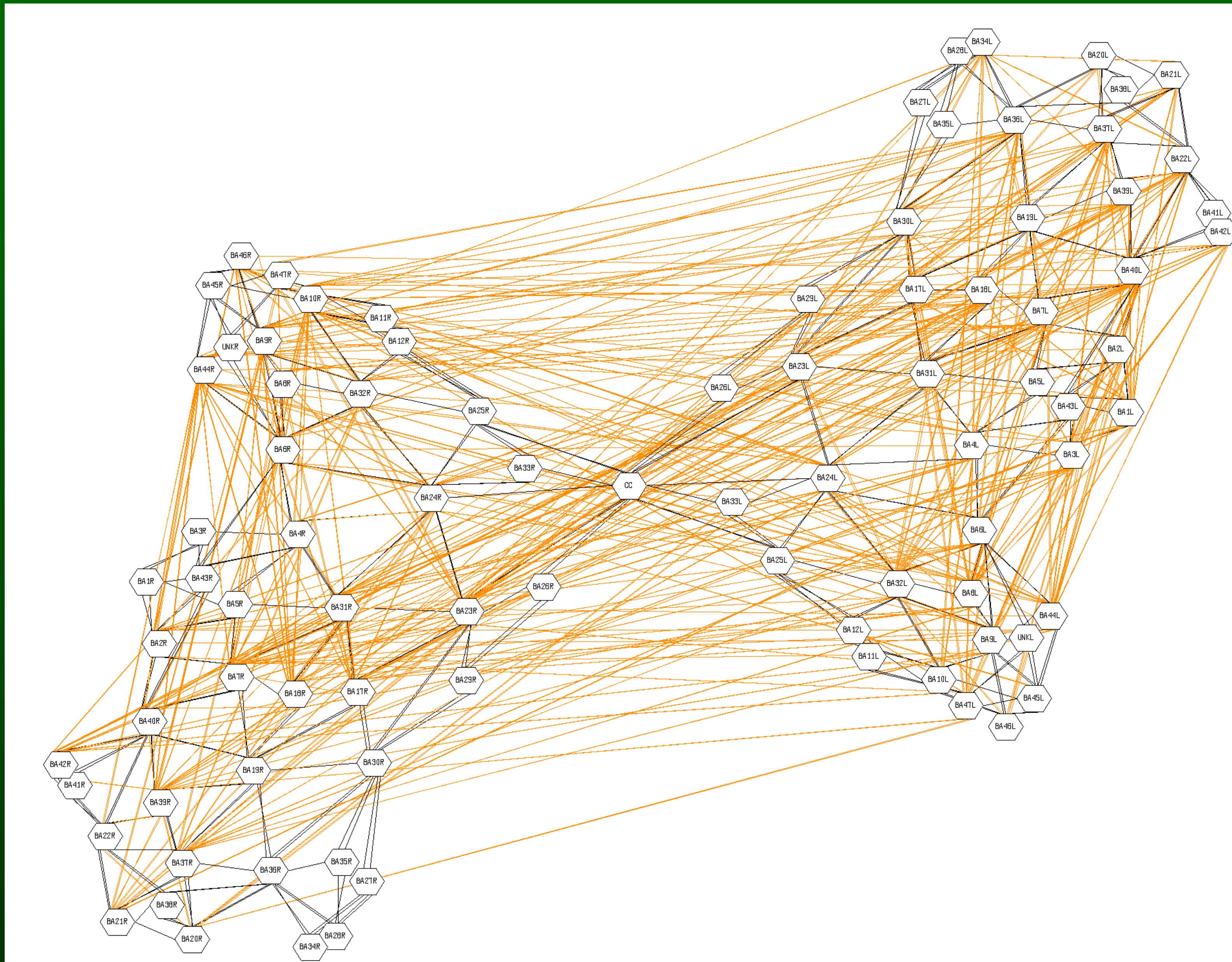


Language (av. of 165 experiments)

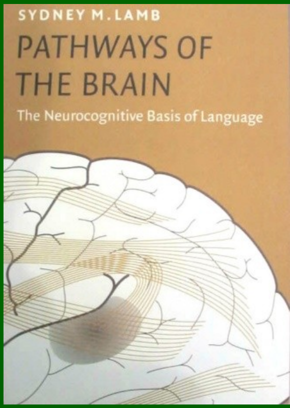


Functional networks, L-R hemispheres, M. Anderson, BBS 2010

Attention functional network

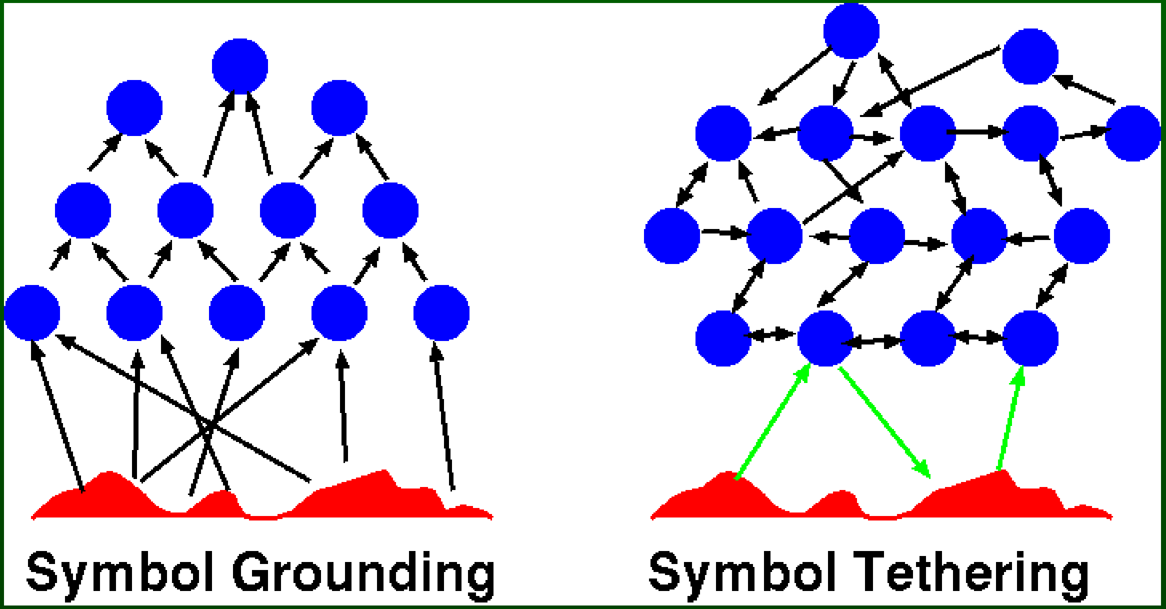


Where is the meaning?



How should the concept meaning be represented?

- No representations, only senso-motoric embodiment (robotics).
- Only some concepts have shared meaning through embodiment.



Aaron Sloman (2007): only simple concepts come from our "being in the world" experience, others are compounds, abstract, for example a "golden mountain".

Not symbol grounding, but symbol tethering, meaning from mutual interactions.

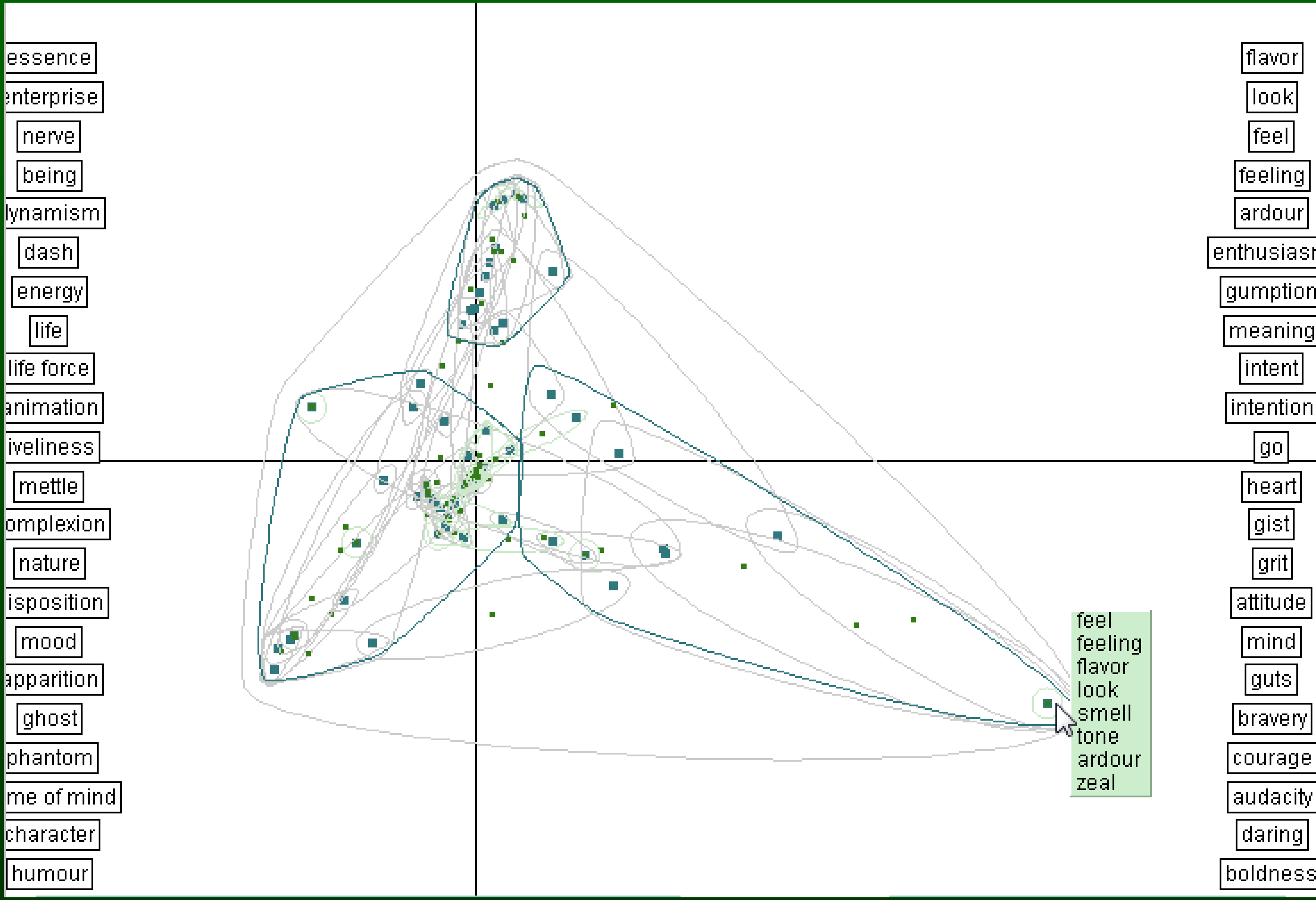
All symbols are percepts of higher-order cortical states.

Semantic Atlas

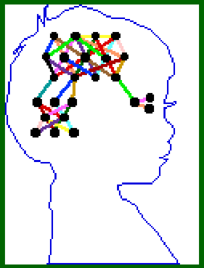
http://dico.isc.cnrs.fr/en/index.html

spirit:
79 words
69 cliques,
or minimal
units of
meaning.

Synset =
set of
synonyms



Words in the brain



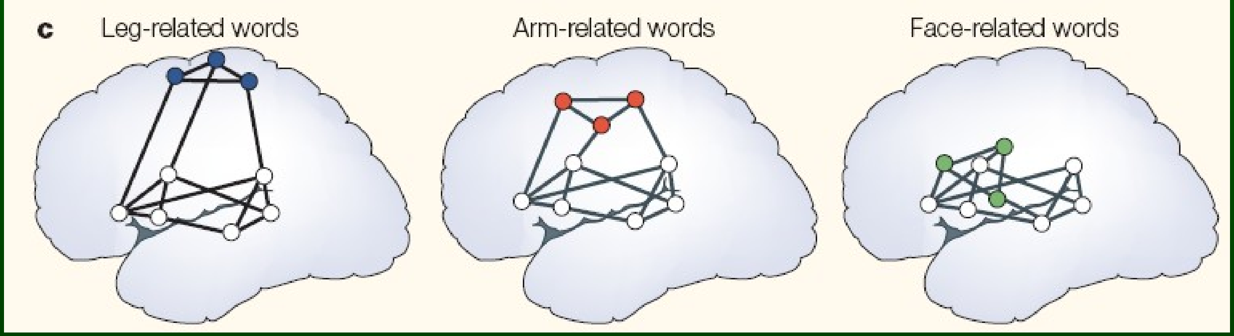
Psycholinguistic experiments show that most likely categorical, phonological representations are used, not the acoustic input.

Acoustic signal => phoneme => words => semantic concepts.

Phonological processing precedes semantic by 90 ms (from N200 ERPs).

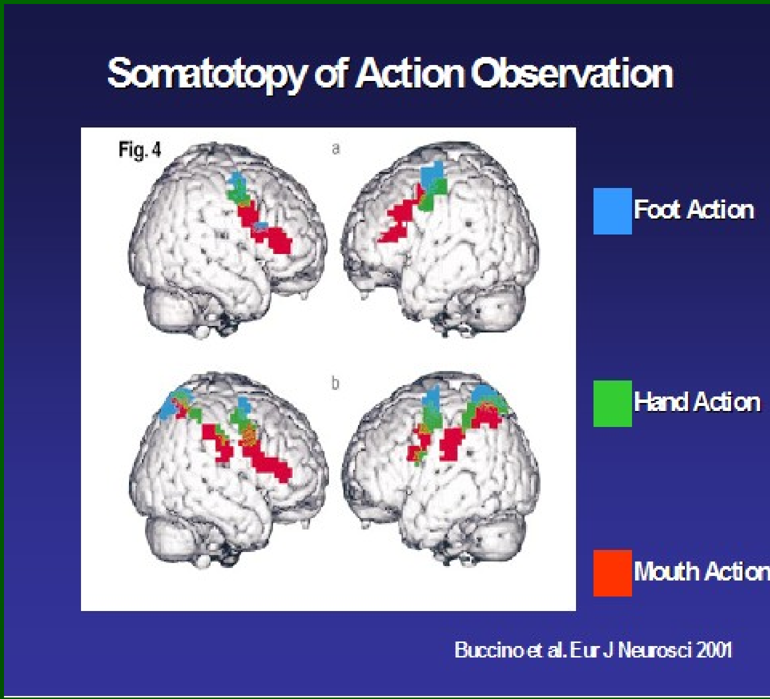
F. Pulvermuller (2003) The Neuroscience of Language. On Brain Circuits of Words and Serial Order. Cambridge University Press.

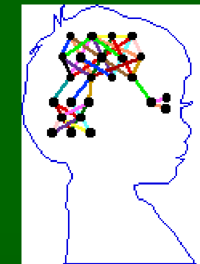
Action-perception networks inferred from ERP and fMRI



Left hemisphere: precise representations of symbols, including phonological components; right hemisphere? Sees clusters of concepts.

s in the brain





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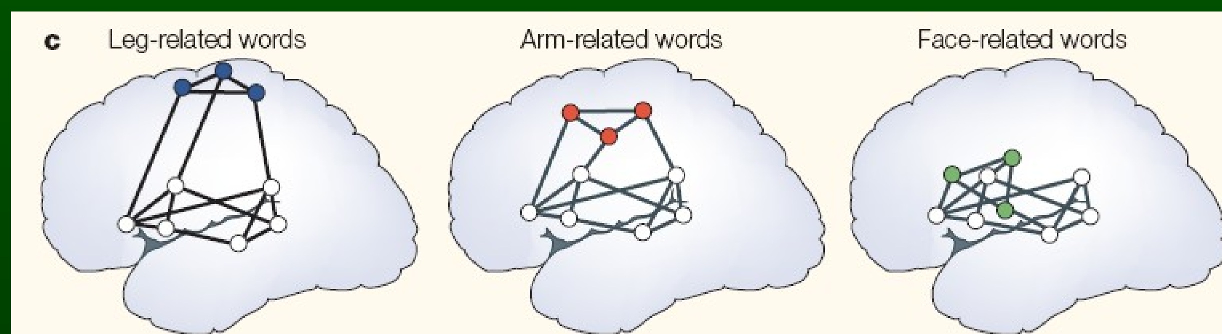

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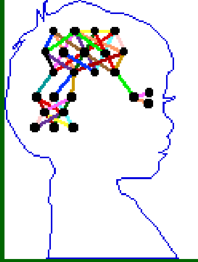
Neuroimaging words

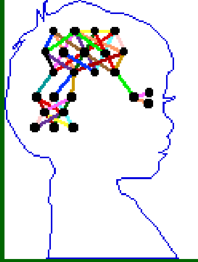


Predicting Human Brain Activity Associated with the Meanings of Nouns," T. M. Mitchell et al, Science, 320, 1191, May 30, 2008

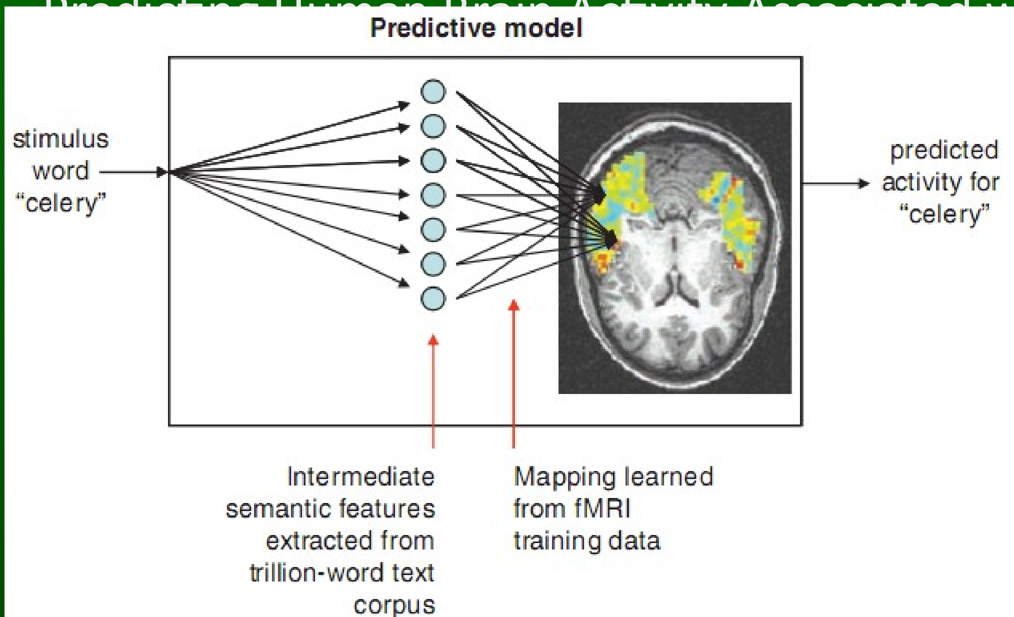
- Clear differences between fMRI brain activity when people read and think about different nouns.
- Reading words and seeing the drawing invokes similar brain activations, presumably reflecting semantics of concepts.
- Although individual variance is significant similar activations are found in brains of different people, a classifier may still be trained on pooled data.
- Model trained on ~10 fMRI scans + very large corpus (10^{12}) predicts brain activity for over 100 nouns for which fMRI has been done.

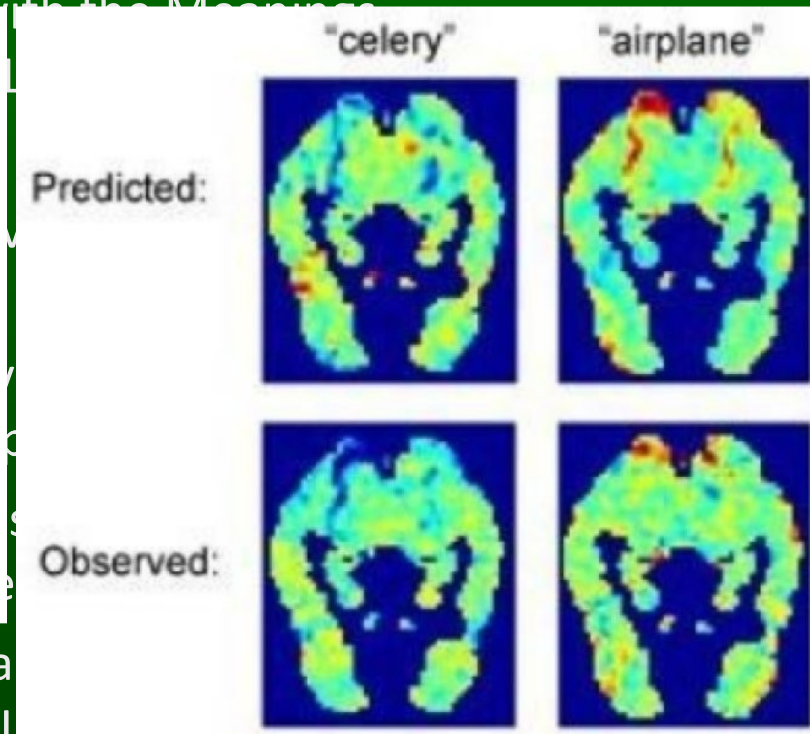
Transform words => vector of 25 semantic features, perception and action.
Sensory: see, hear, touch, smell, taste, fear.
Motor: eat, manipulate, move, pick, push, stroke, talk, run, walk.
Actions: break, ride, clean, enter, fill, open, carry.

Neuroimaging words



Predicting Human Brain Activity Associated with the Meanings





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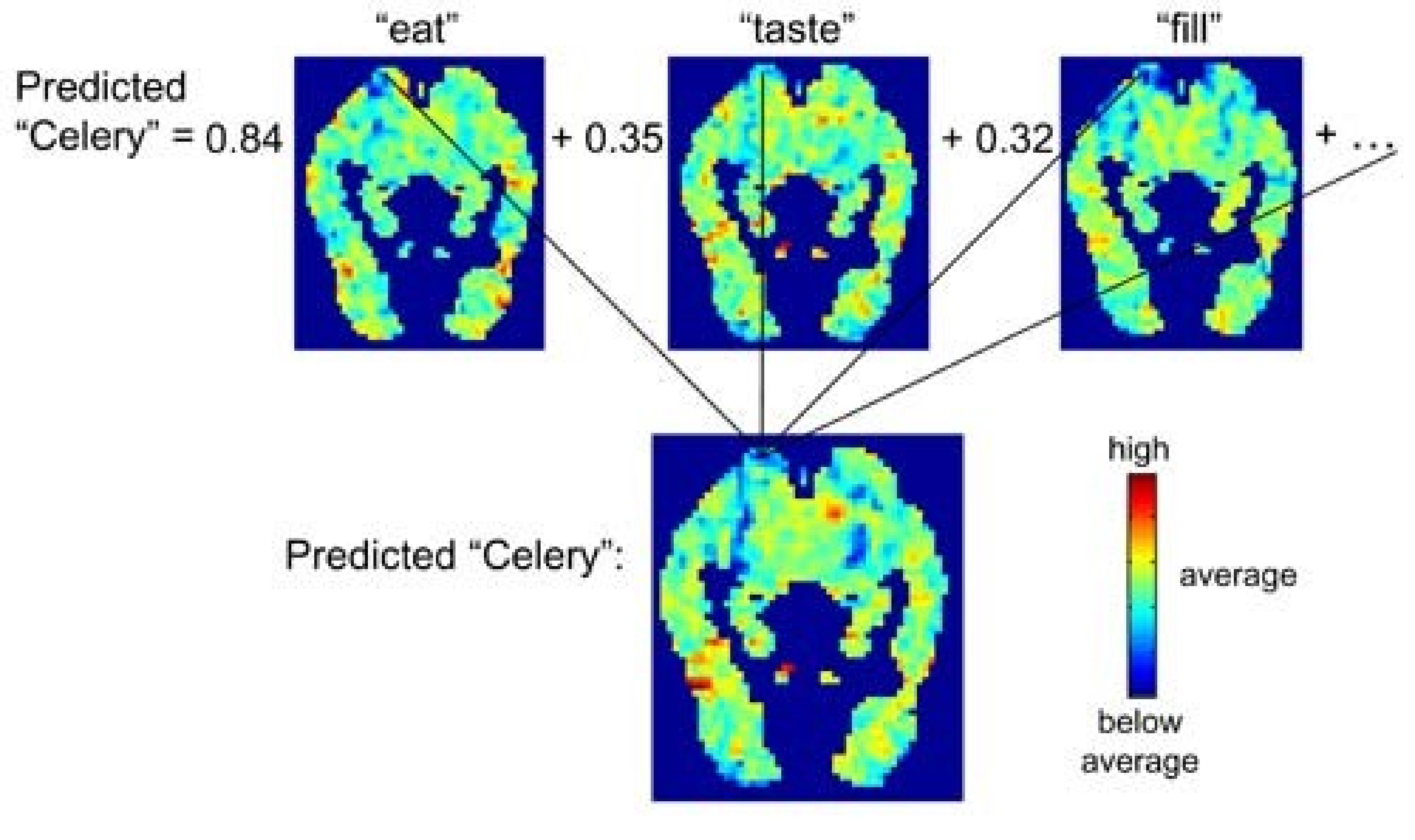


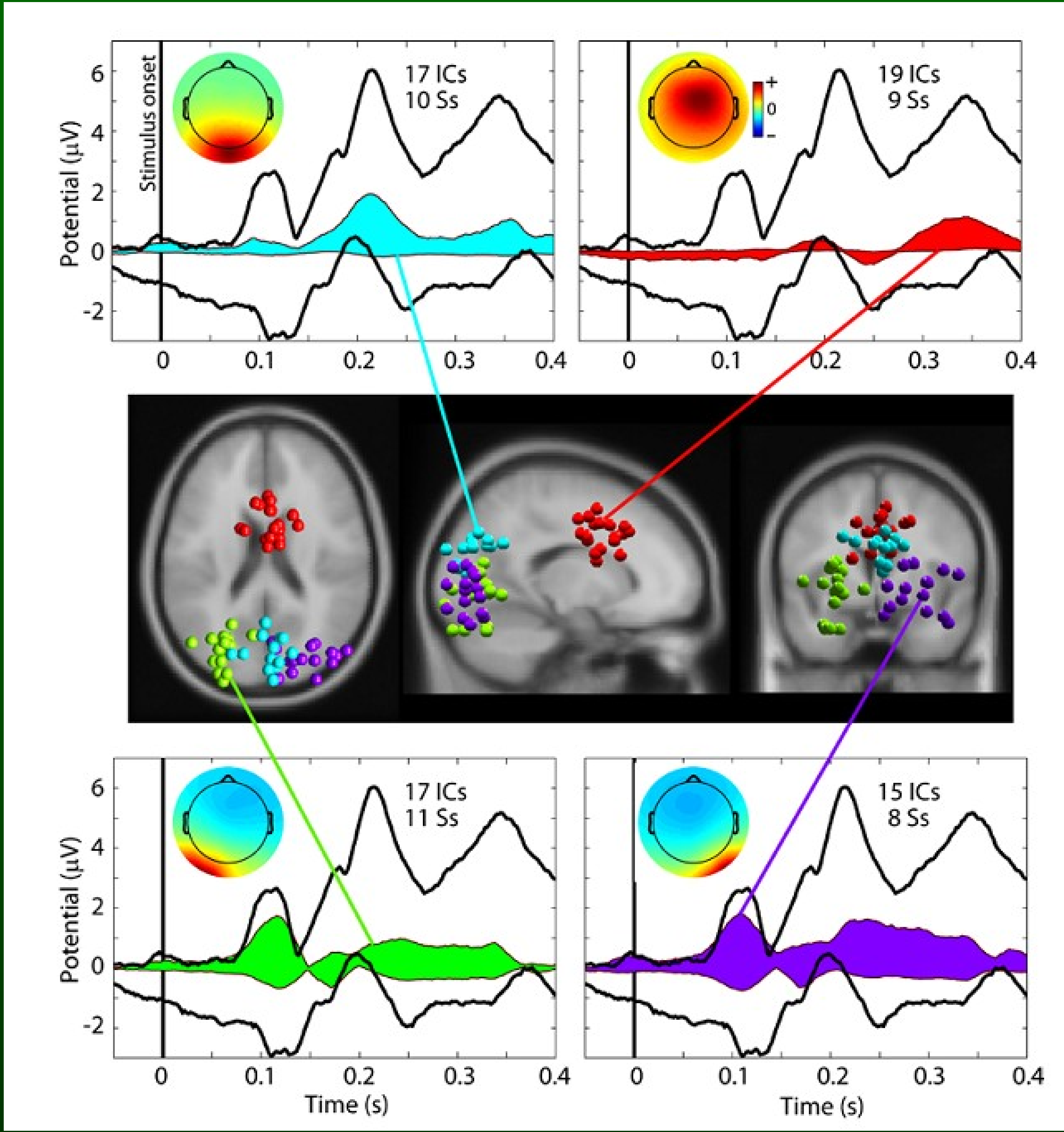
"eat"
"taste"
"fill"
Predicted
"Celery" = 0.84
+ 0.35
+ 0.32
+ ...
Predicted "Celery":
high
average
below
average

Source localization maps brain activity to attractor dynamics.

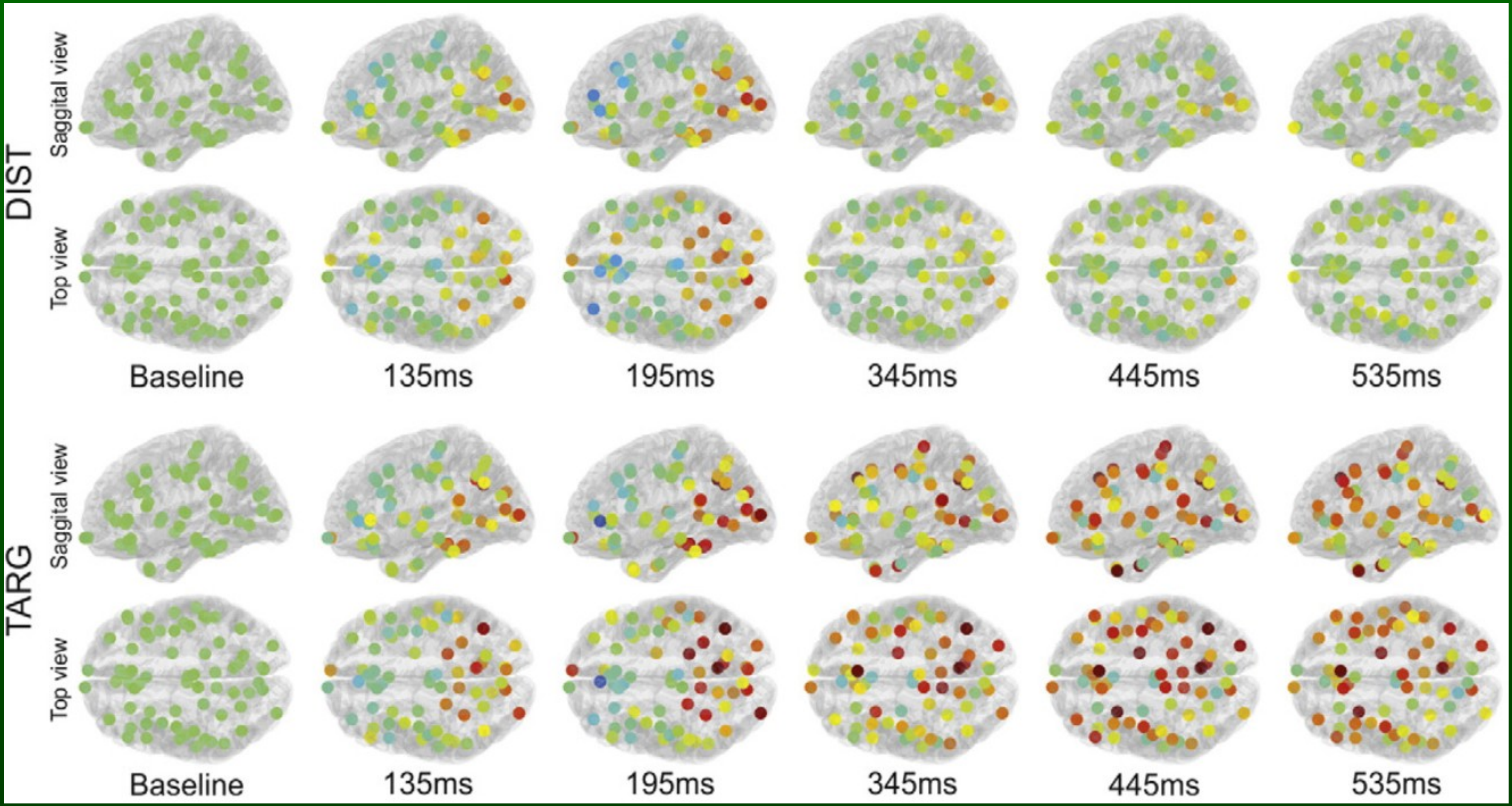
Problem: these sources pop up and vanish in different places.

Fig. from:
Makeig, Onton, 2009
ERP Features and
EEG Dynamics:
An ICA Perspective.

Brain fingerprinting: discover in EEG specific patterns identifying attractor dynamics = subnetwork activation.



Priming activates subnetworks



M Bola, B.A. Sabel, Dynamic reorganization of brain functional networks during cognition. NeuroImage 114 (2015) 398–413 (EEG PLV)

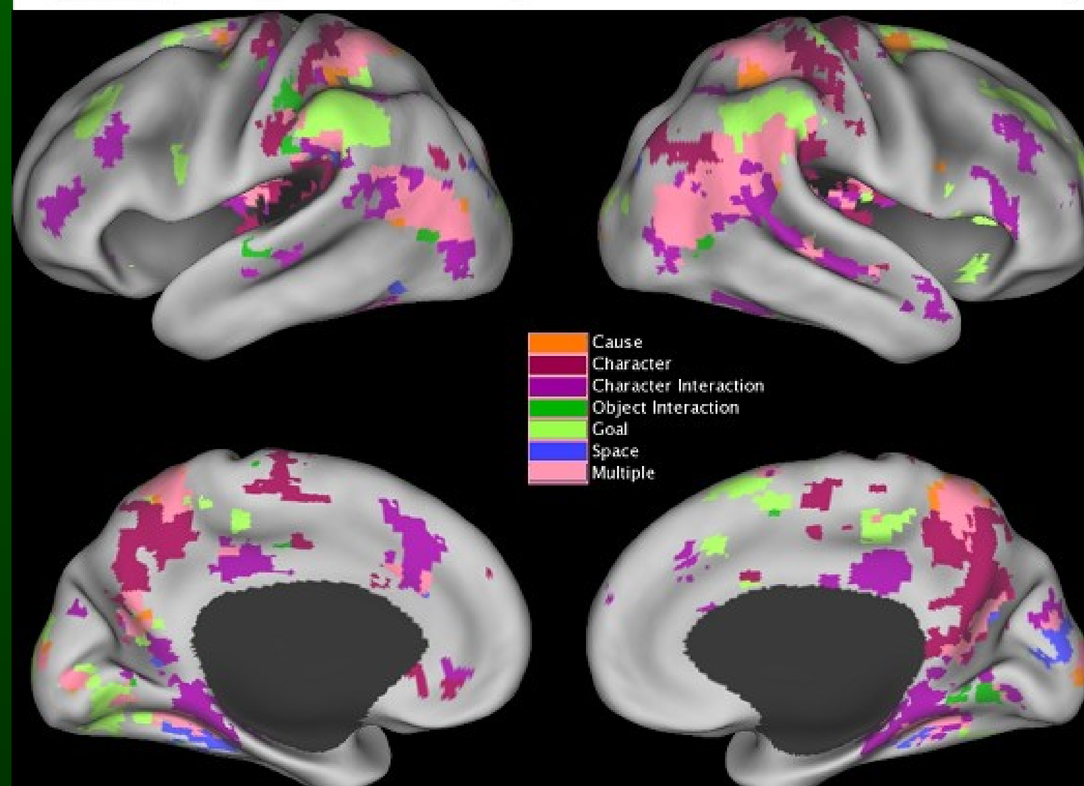
Nicole Speer et al. Reading Stories Activates Neural Representations of Visual and Motor Experiences. *Psychological Science* (2010).

Meaning: always slightly different, depending on the context, but still may be clustered into relatively small number of distinct meanings.

Experience is segmented into scenes, changes lead to reconfiguration of brain activations. Easier to analyze, remember, find invariants.

A

Clause	Cause	Character	Goal	Object	Space	Time
...[Mrs. Birch] went through the front door into the kitchen.	●				●	
Mr. Birch came in	●	●			●	
and, after a friendly greeting,	●					●
chatted with her for a minute or so.	●					●
Mrs. Birch needed to awaken Raymond.		●				
Mrs. Birch stepped into Raymond's bedroom,			●		●	
pulled a light cord hanging from the center of the room,				●		
and turned to the bed.						
Mrs. Birch said with pleasant casualness,						
"Raymond, wake up."						
With a little more urgency in her voice she spoke again:						
Son, are you going to school today?						
Raymond didn't respond immediately.		●				●
He screwed up his face			●			
And whimpered a little.						



Logic and language

Form matters!

Logic arguments with sentential connectives:
if both X and Z then not Y, or if Y then either not X or not Z.

Linguistic arguments:
It was X that Y saw Z take, or Z was seen by Y taking X, phrasal verbs.

The ability to use logic and understand language may dissociate.

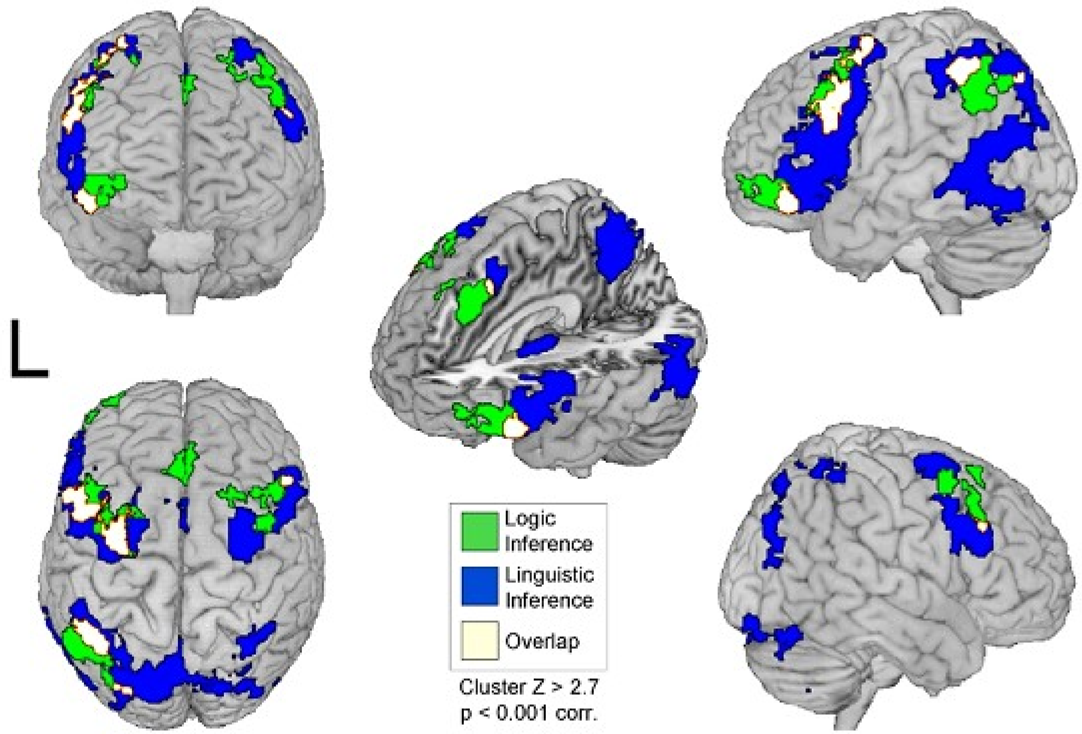
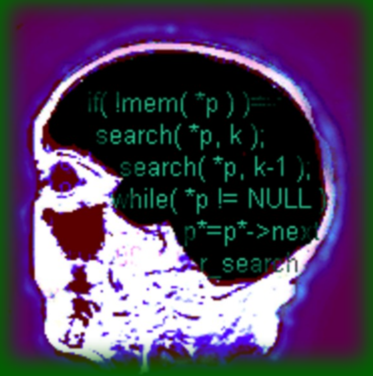


Fig. 1. Inference minus grammar contrast. Mean group activity for logic arguments (green/yellow) and linguistic arguments (blue/yellow).

M.M. Monti, L.M. Parsons, D.N. Osherson, The boundaries of language and thought: neural basis of inference making. PNAS 2009

Neurocognitive informatics



Use inspirations from the brain, derive practical algorithms!

My own attempts - see my webpage, Google: W. Duch

1. Mind as a shadow of neurodynamics: **geometrical model of mind** processes, psychological spaces providing inner perspective as an approximation to neurodynamics.
2. **Intuition**: learning from partial observations, solving problems without explicit reasoning (and combinatorial complexity) in an intuitive way.
3. **Neurocognitive linguistics**: how to find neural pathways in the brain.
4. **Creativity** in limited domains + word games, good fields for testing.

Duch W, Intuition, Insight, Imagination and Creativity, IEEE Computational Intelligence Magazine 2007

Duch W, Matykiewicz P, Pestian J, Neurolinguistic Approach to Natural Language Processing. Neural Networks 2008

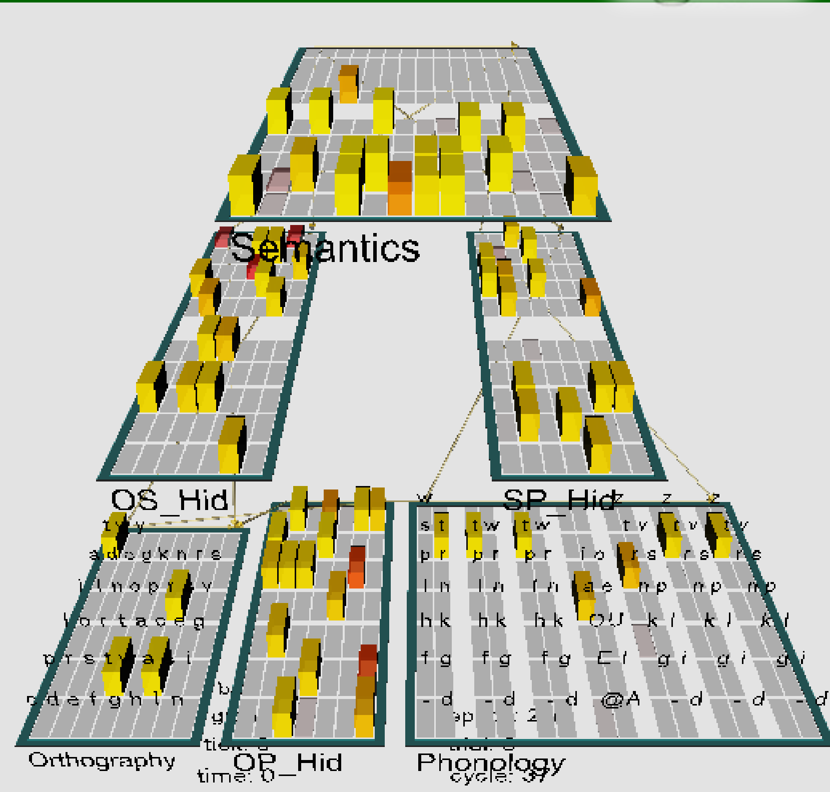
Model of reading & dyslexia

Emergent neural simulator:

B. Aisa, B. Mingus, R. O'Reilly,
The emergent neural modeling system.
Neural Networks, 2008.

3-layer model of reading:

Recurrent neural network (RNN) with orthography, phonology, and semantic layer = activity of 140 microfeatures that define concepts by distribution of their activations.



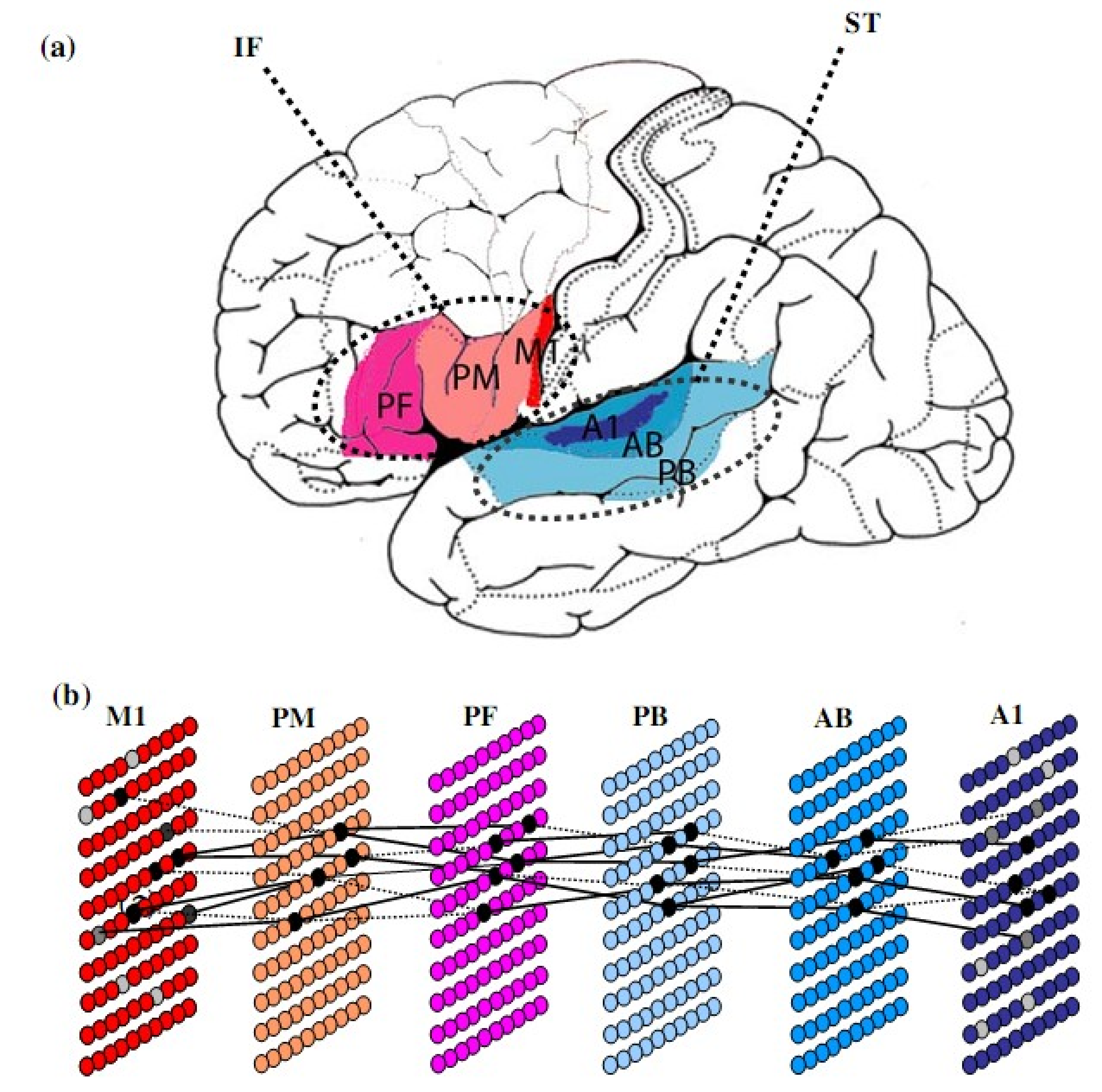
Word (written or spoken) presentation => activate semantics, quickly reaching specific configuration of fluctuating active units ⇔ attractor representing concept. Transition to related attractor soon follows.
Sequence of attractor states can be labeled by the activity of phonological or orthographical layers, stream of verbal comments on internal state.

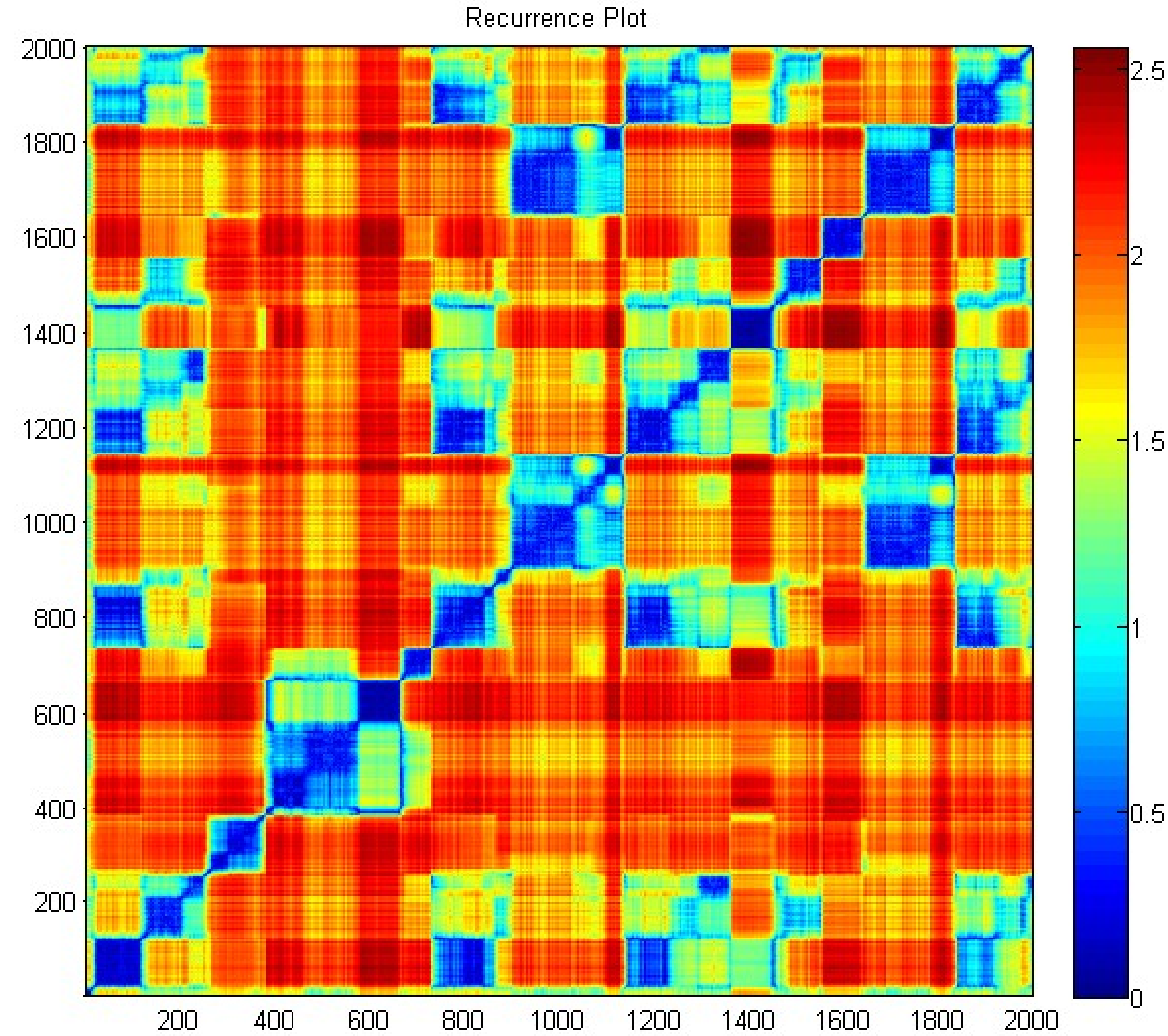
Detailed model

Recruitment and consolidation of cell assemblies for words by way of Hebbian learning and competition in a multi-layer neural network.

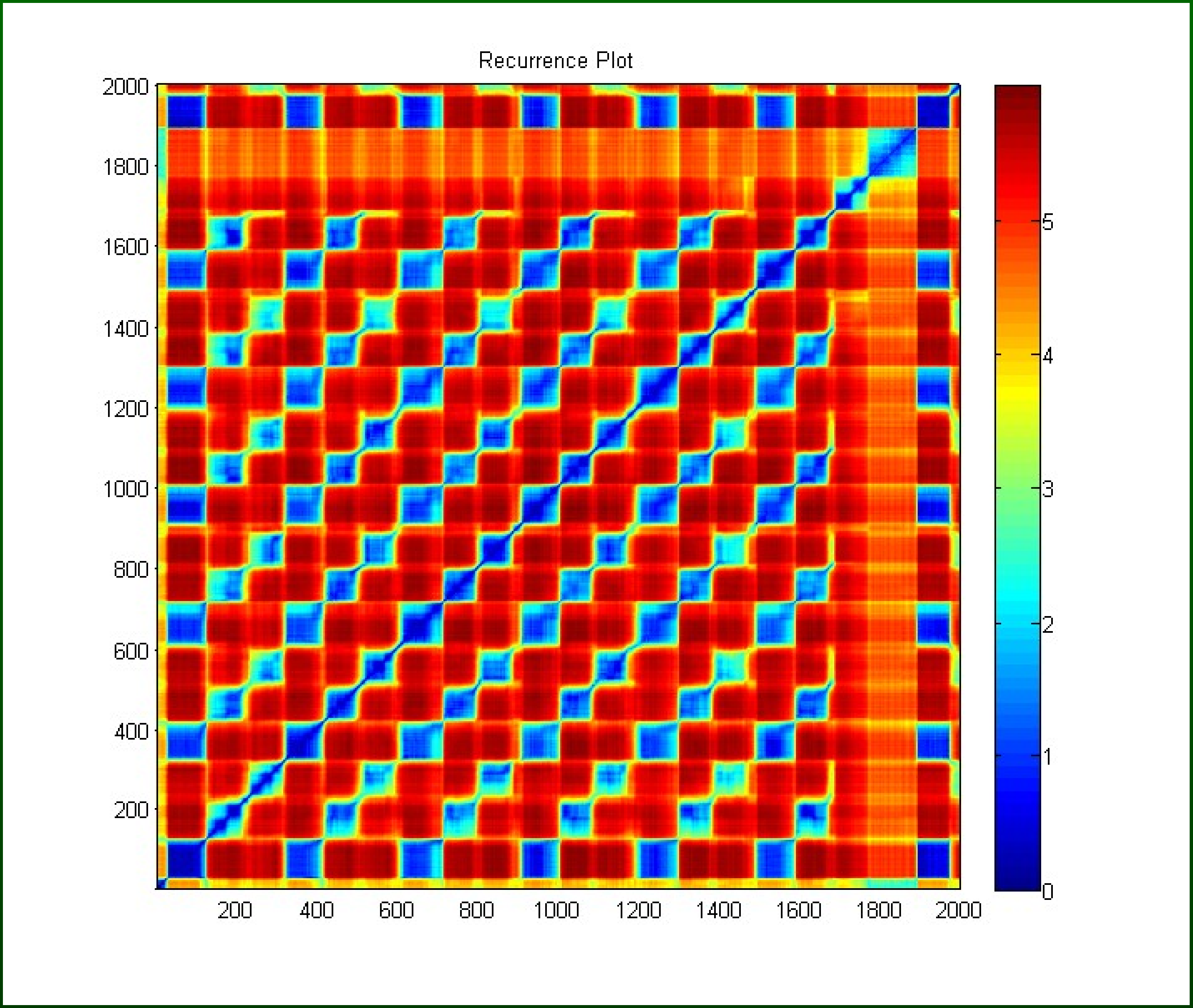
Primary auditory cortex (A1), auditory belt (AB), extended belt (PB, Wernickie area), lateral ventral prefrontal cortex (PF), premotor cortex (PM, Broca), and motor cortex (M1).

Garagnani et al. Cognitive Comp. 1(2), 160-176, 2009.



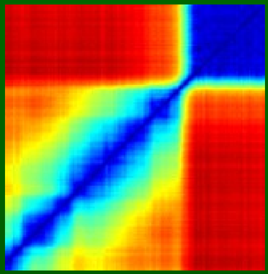


„Gain" – for abstract words semantic layer trajectory rarely comes back to similar states, there are fewer attractors than for the concrete words.



„Deer" – trajectory of the semantic layer goes through some transient states and tends to come back to original attractor, near the end moving far from it.

Fuzzy Symbolic Dynamics (FSD)



Complementing information in RPs:

RP plots $S(t,t_0)$ values as a matrix; FSD

1. Standardize data.
2. Find cluster centers (e.g. by k-means algorithm): $\mu_1, \mu_2 \ldots$
3. Use non-linear mapping to reduce dimensionality:

$$y_k(t;\boldsymbol{\mu}_k,\Sigma_k) = \exp\left(-\left(\mathbf{x}(t)-\boldsymbol{\mu}_k\right)^{\mathrm{T}} \Sigma_k^{-1}\left(\mathbf{x}(t)-\boldsymbol{\mu}_k\right)\right)$$

Localized membership functions $y_k(t;W)$:

sharp indicator functions => symbolic dynamics; $x(t)$ => strings of symbols;

soft membership functions => fuzzy symbolic dynamics, dimensionality reduction $Y(t)=(y_1(t;W), y_2(t;W))$ => visualization of high-dim data.

We may then see visualization of trajectory in some basin of attraction. Such visualizations are simply referred to as “attractors”.

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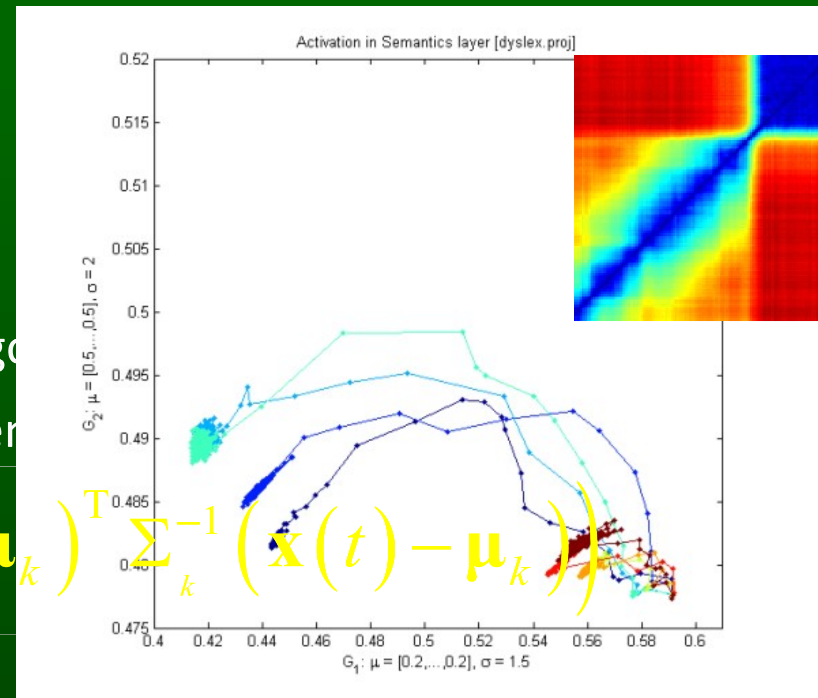

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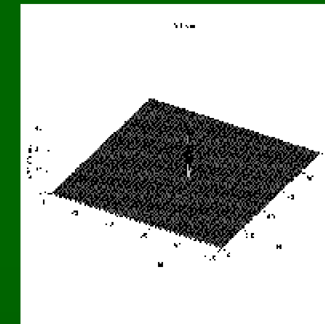
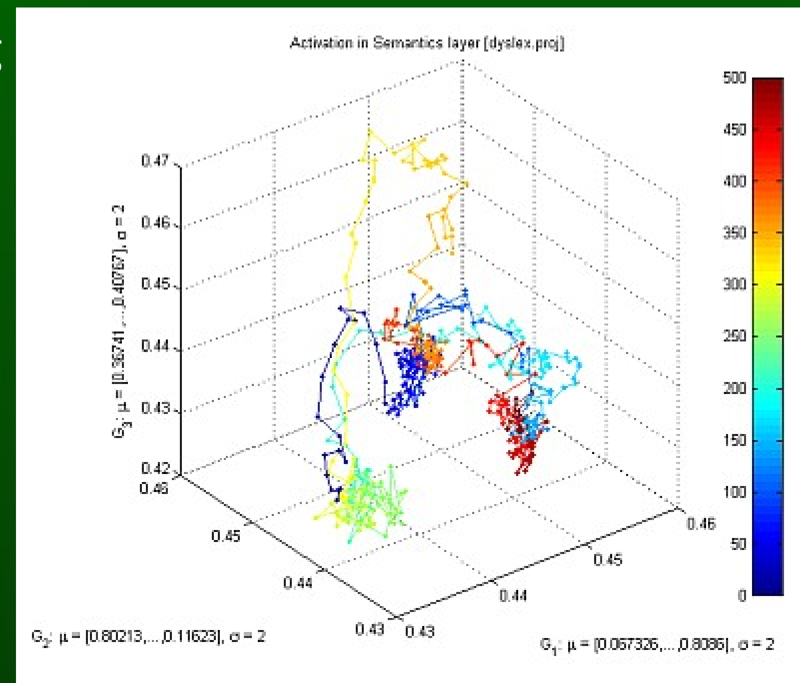
Basins of attractors



Groups of neurons synchronize, become highly active, these activations fluctuate around some specific distributions, inhibiting competing groups of neurons.

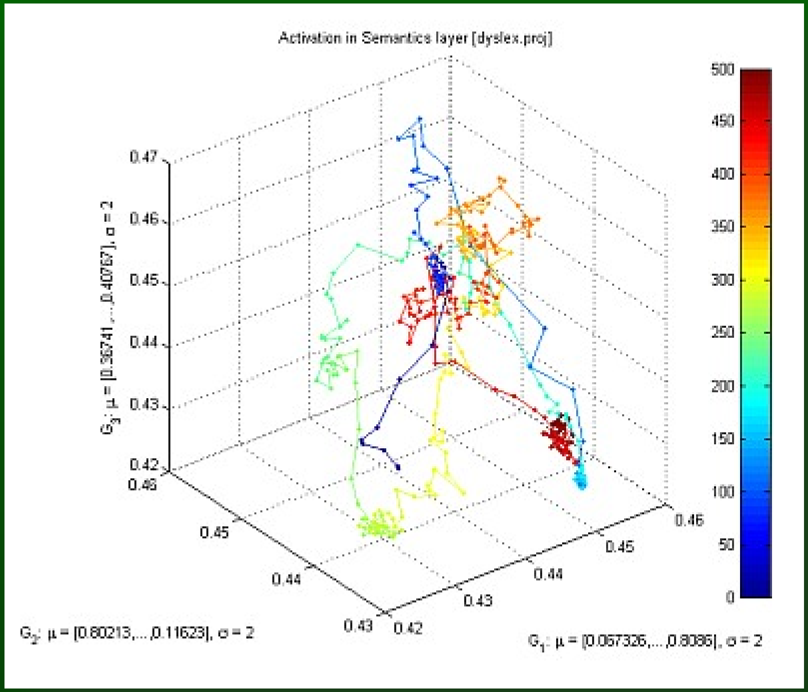
Normal case: relatively large, easy associations, fast transitions from one basin of attraction to another, creating "stream of consciousness".

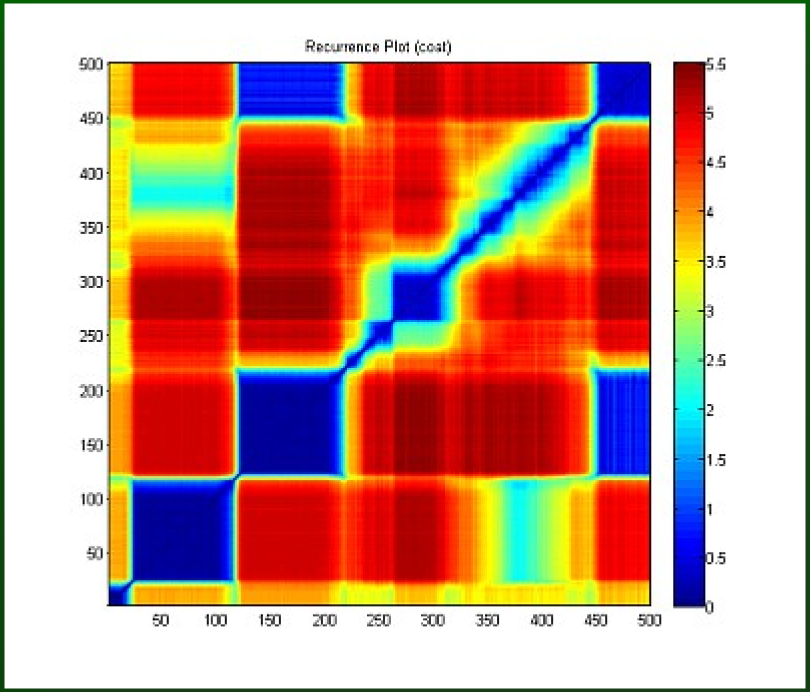
Brain has about 3 mln minicolumns in the cortex alone, corresponding to units in computational model, so this is a huge space. Here each point ⇔ 140 dim. vector.



Accessible basins of attractors = available mental states that can be categorized and identified. They shrink and vanish as neurons desynchronize due to the fatigue; this allows other neurons to synchronize, leading to new mental states (thoughts).

Fast transitions

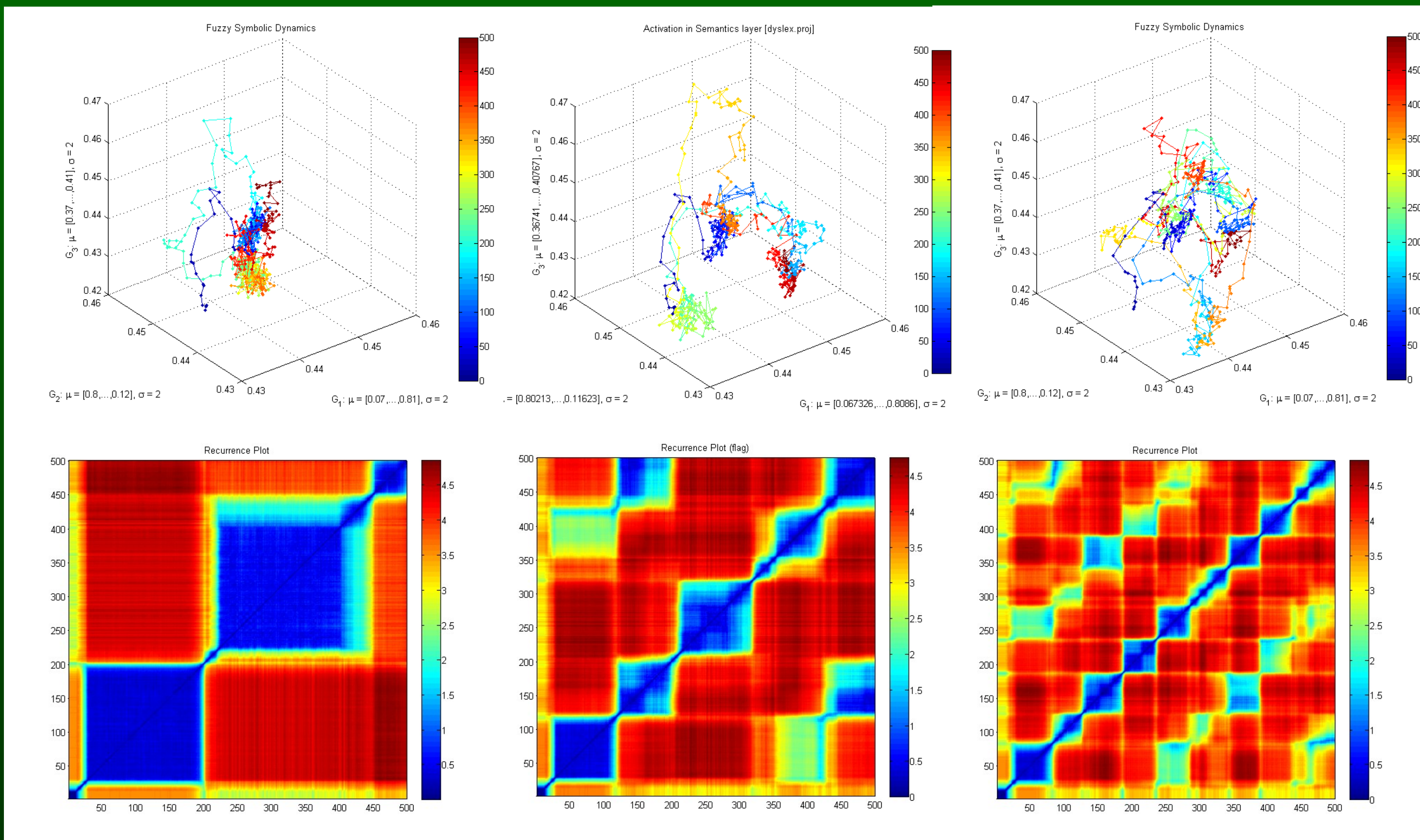




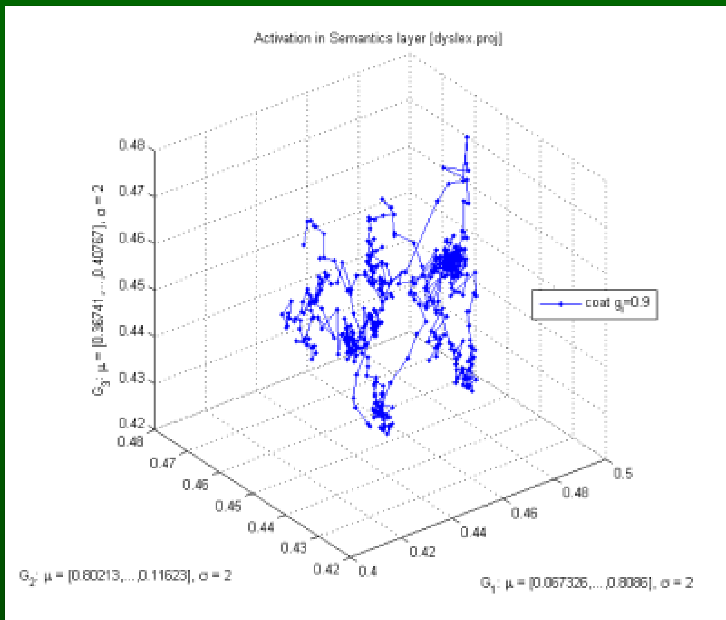
Attention is focused only for a brief time and than moved to the next attractor basin, some basins are visited for such a short time that no action may follow, no chance for other neuronal groups to synchronize. This corresponds to the feeling of confusion, not being conscious of fleeting thoughts.

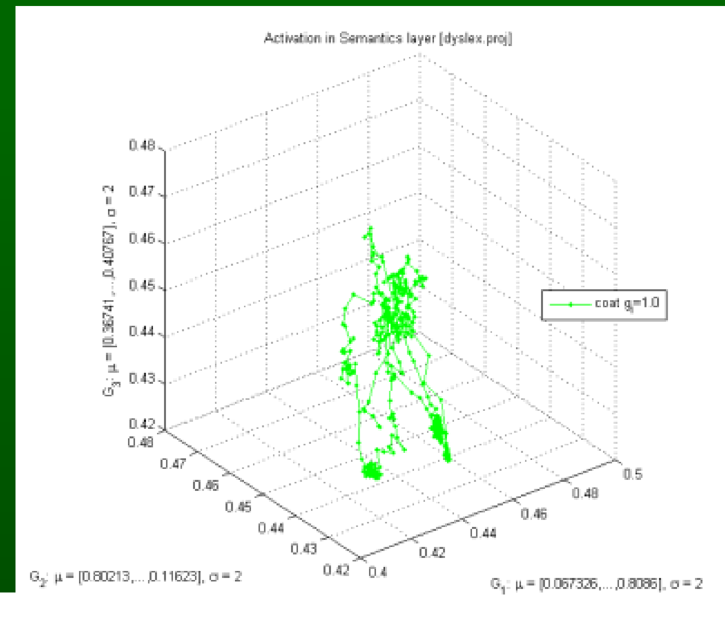
Autism-Normal-ADHD

b_inc_dt = 0.005 | *b_inc_dt* = 0.01 | *b_inc_dt* = 0.02

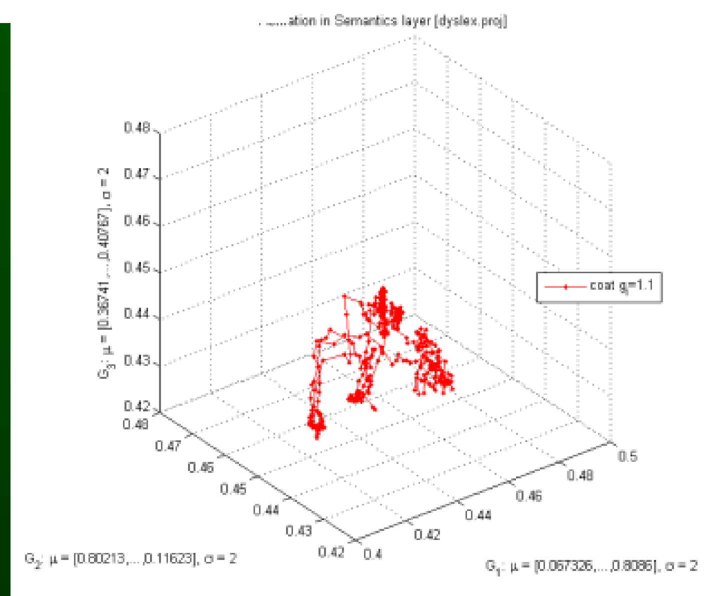


Inhibition



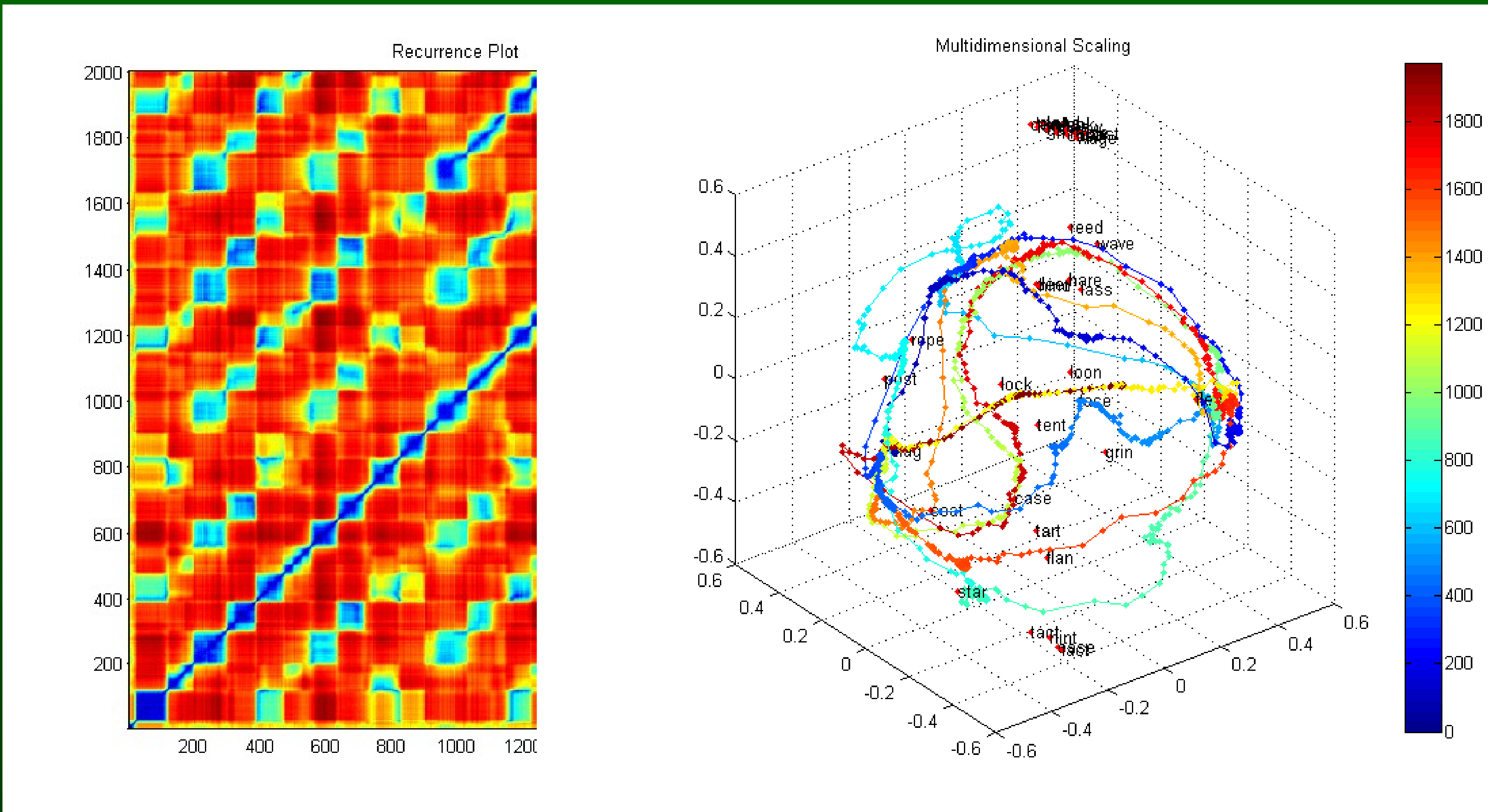


Increasing g_i from 0.9 to 1.1 reduces the attractor basin sizes and simplifies trajectories.

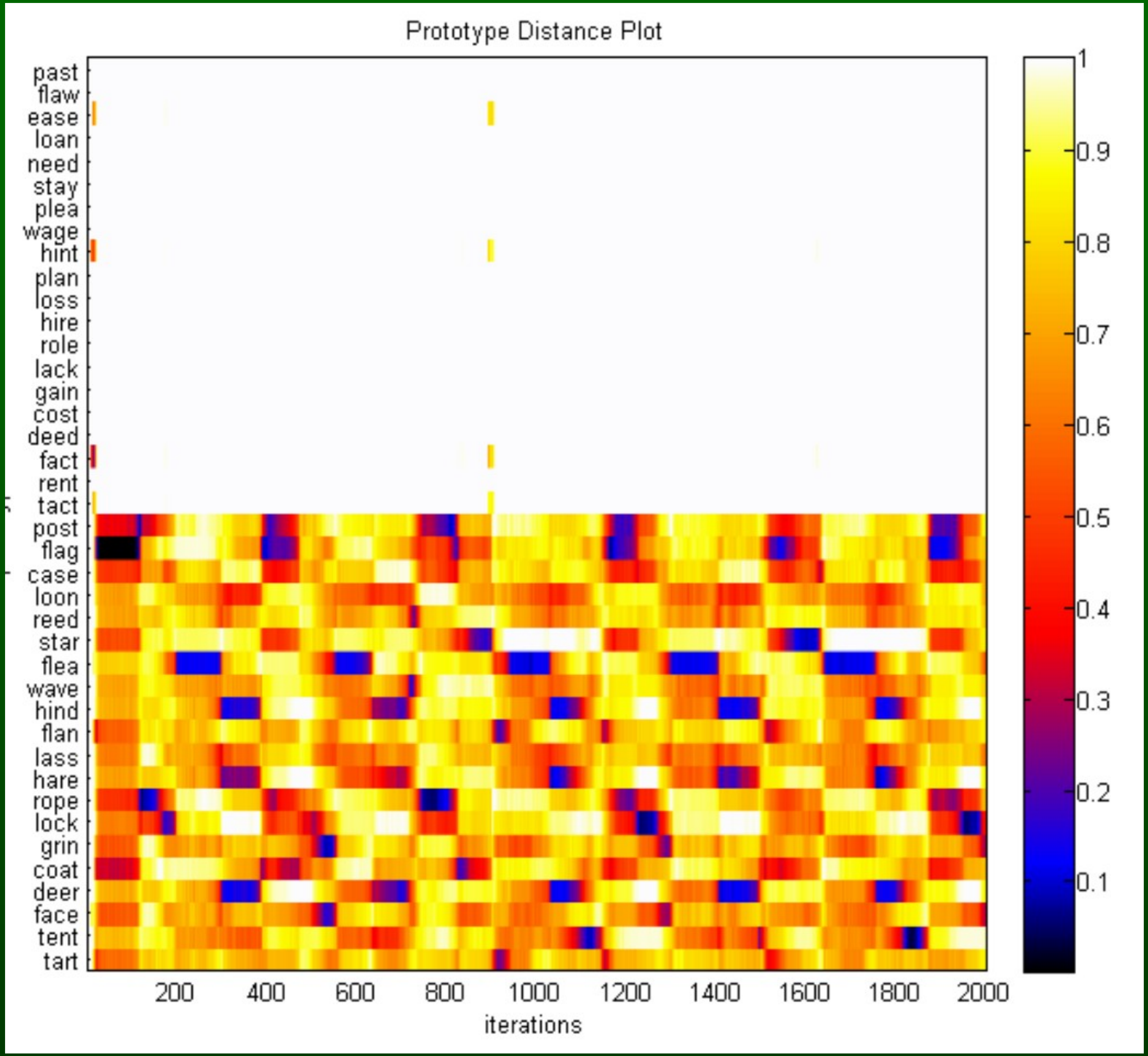


Strong inhibition, empty head …

Long trajectories



Recurrence plots and MDS visualization in 40-words microdomain, starting with the word “flag”.



PDP for transitions starting from „flag”

MDS word mapping

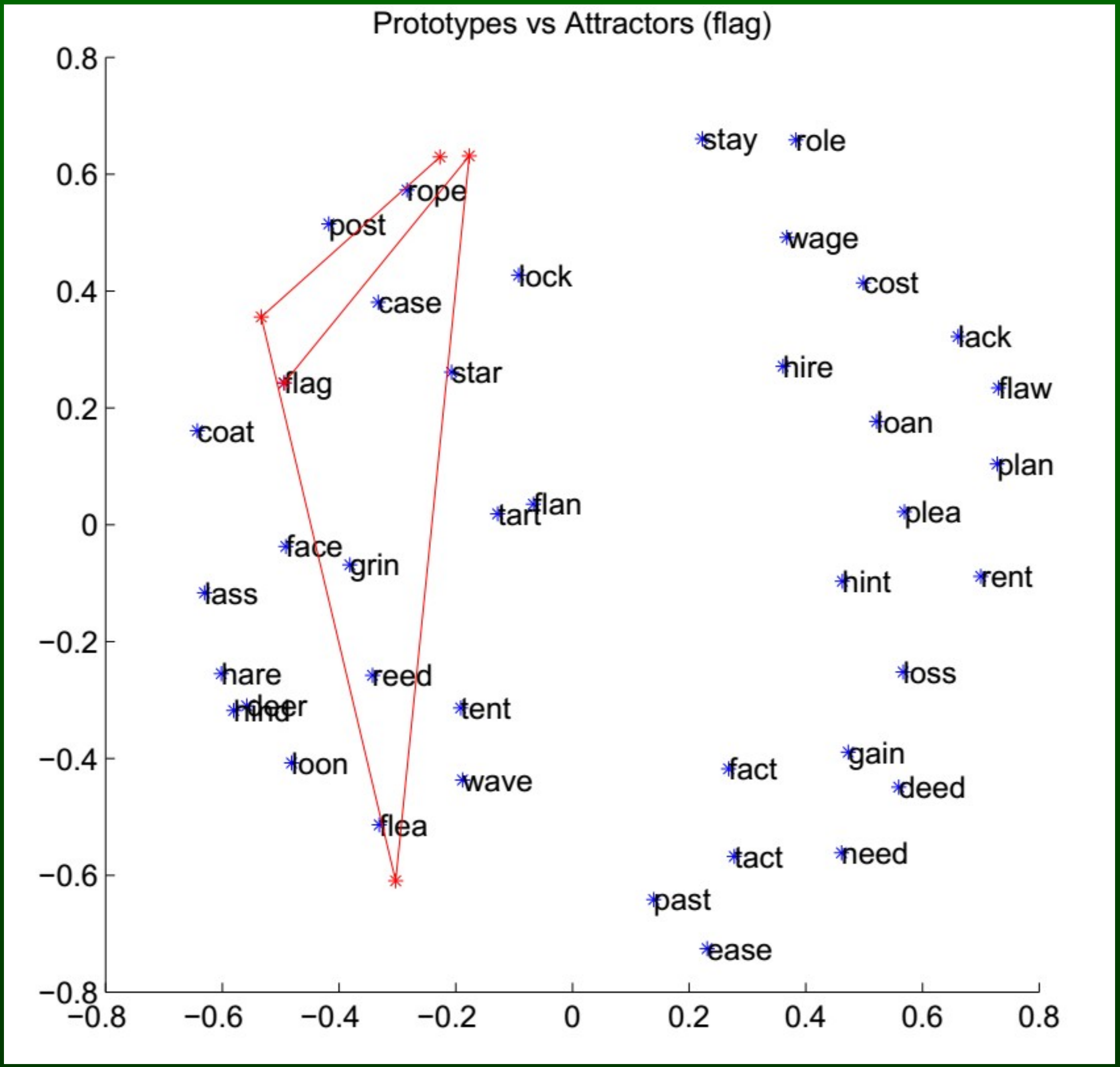
MDS representation of all 40 words, showing similarities of their 140 dimensional vectors.

Attractors are in some cases far from words.

Transition

Flag => rope => flea ...

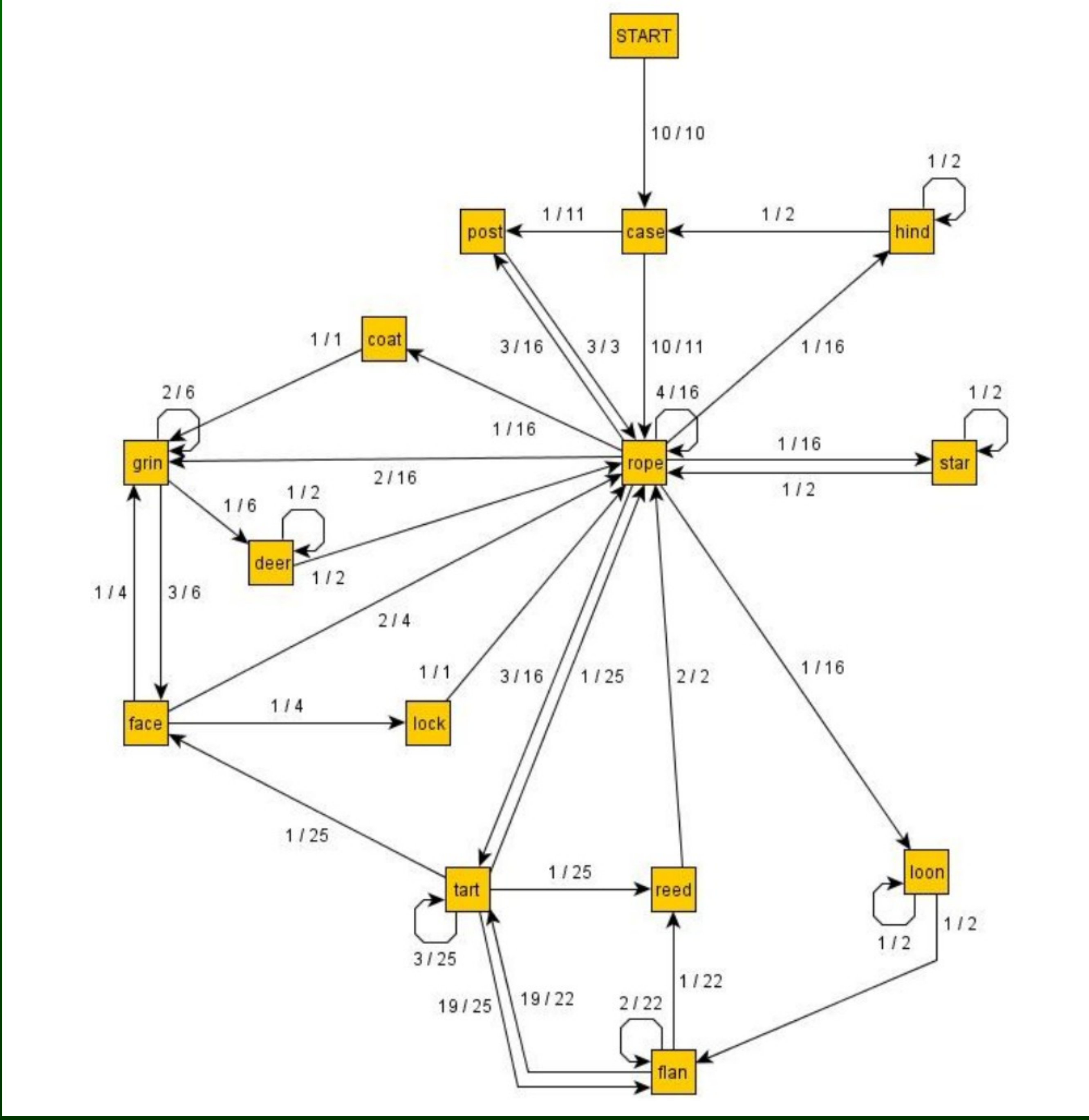
Can we make semantic map of concepts in real brains? See trajectories of thought?

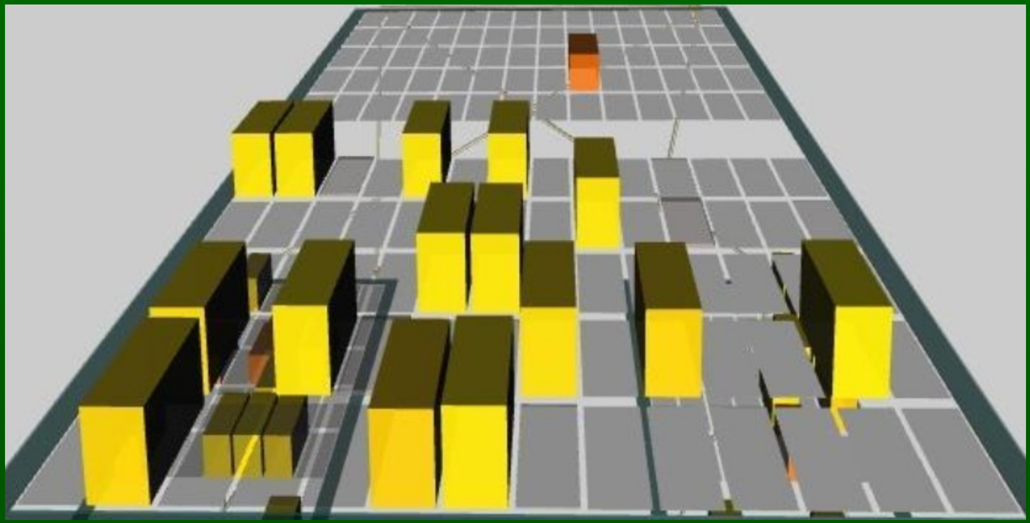


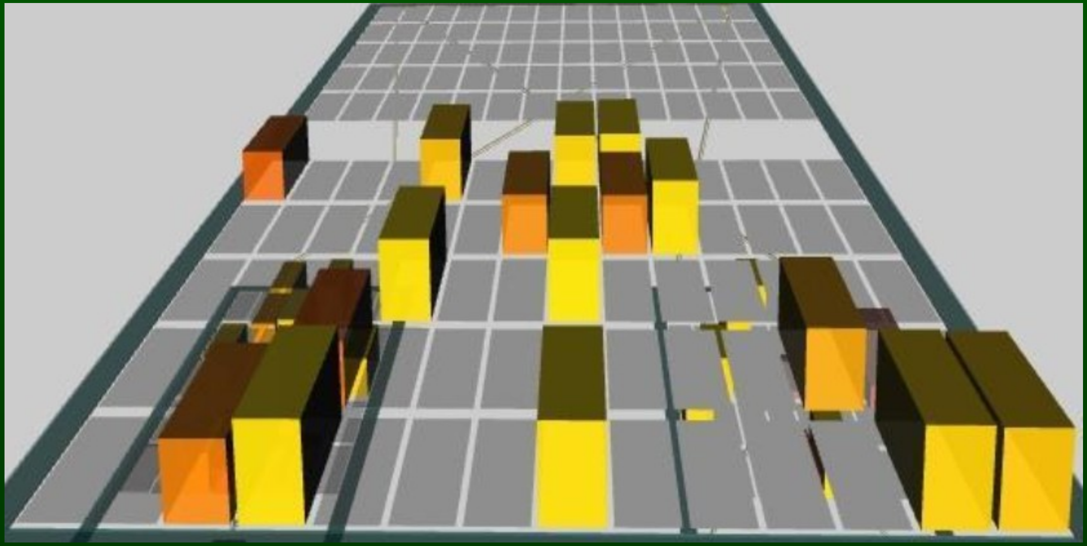
Graph of transitions between attractors after 10 runs.

Why these particular transitions?

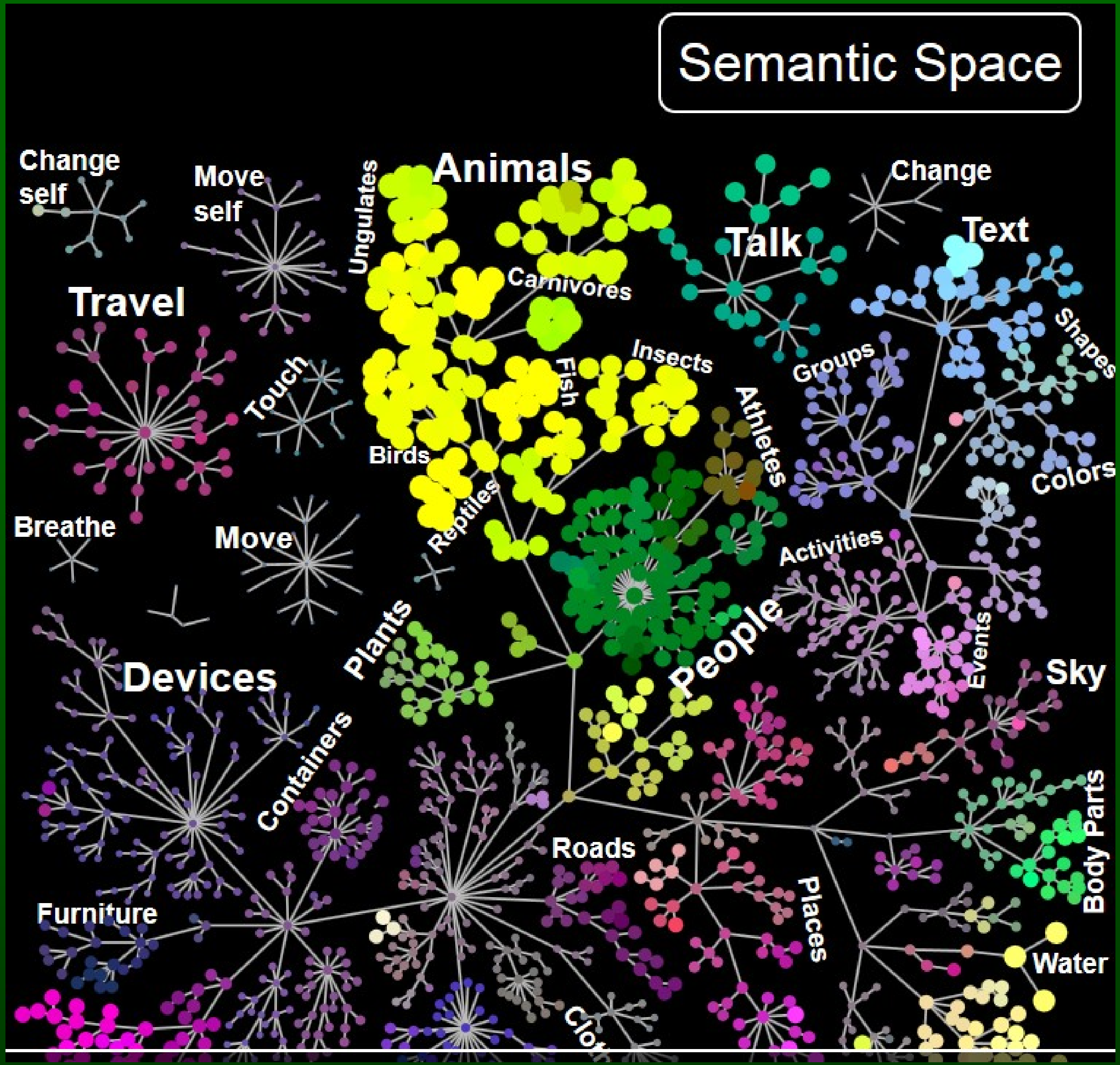
Escape from attractors makes some micro-features (neural units) stronger and some weaker. Visualization using RP or FSD does not show such details. The whole landscape of available attractors is very dynamic! Transition probabilities change, dimensions (features) are rescaled.



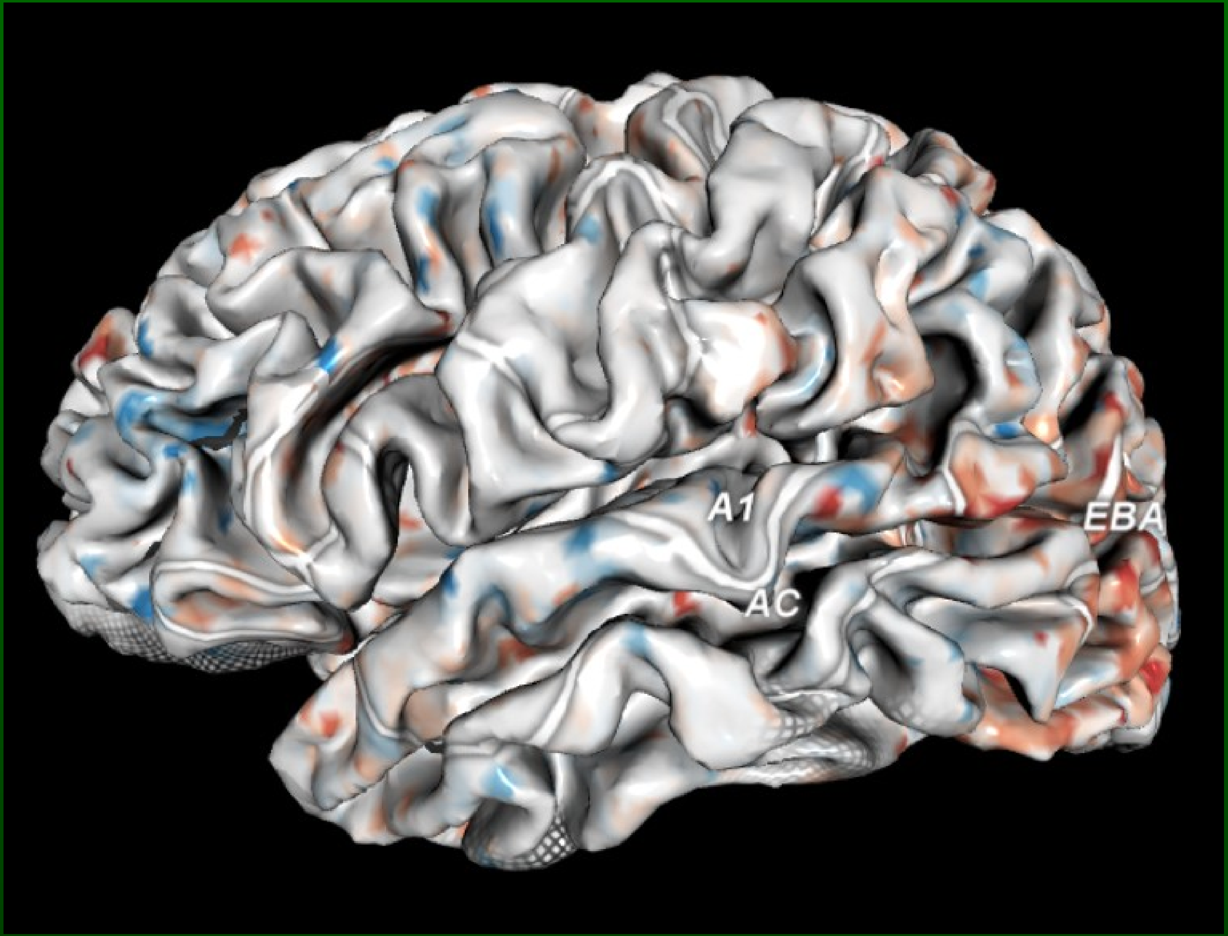




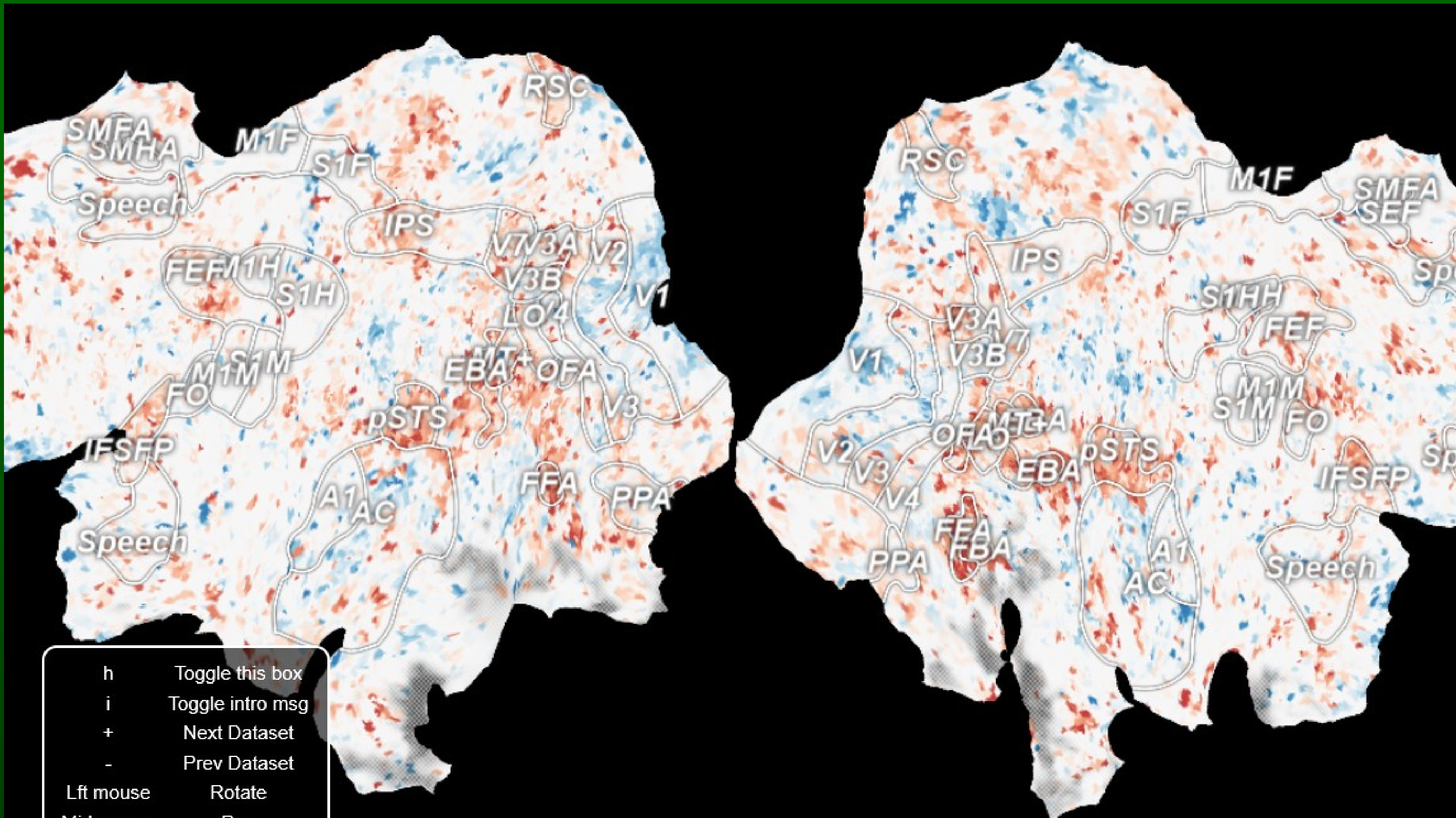
Transition from “case” to “rope”.



Activation of concepts in our minds leads to specific brain structure activity; each structure is involved in interpretation of many concepts (Gallant lab).



Activation of specific concept/mental state/musical phrase leads to activation of a network of specific structures in the whole brain, contributing to sematic interpretation of the perceived meaning through global brain activity.



This activation is sparse and may be better observed by looking at the flattened cortex: http://gallantlab.org/brainviewer/huthetal2012/
It has not been done yet for music …

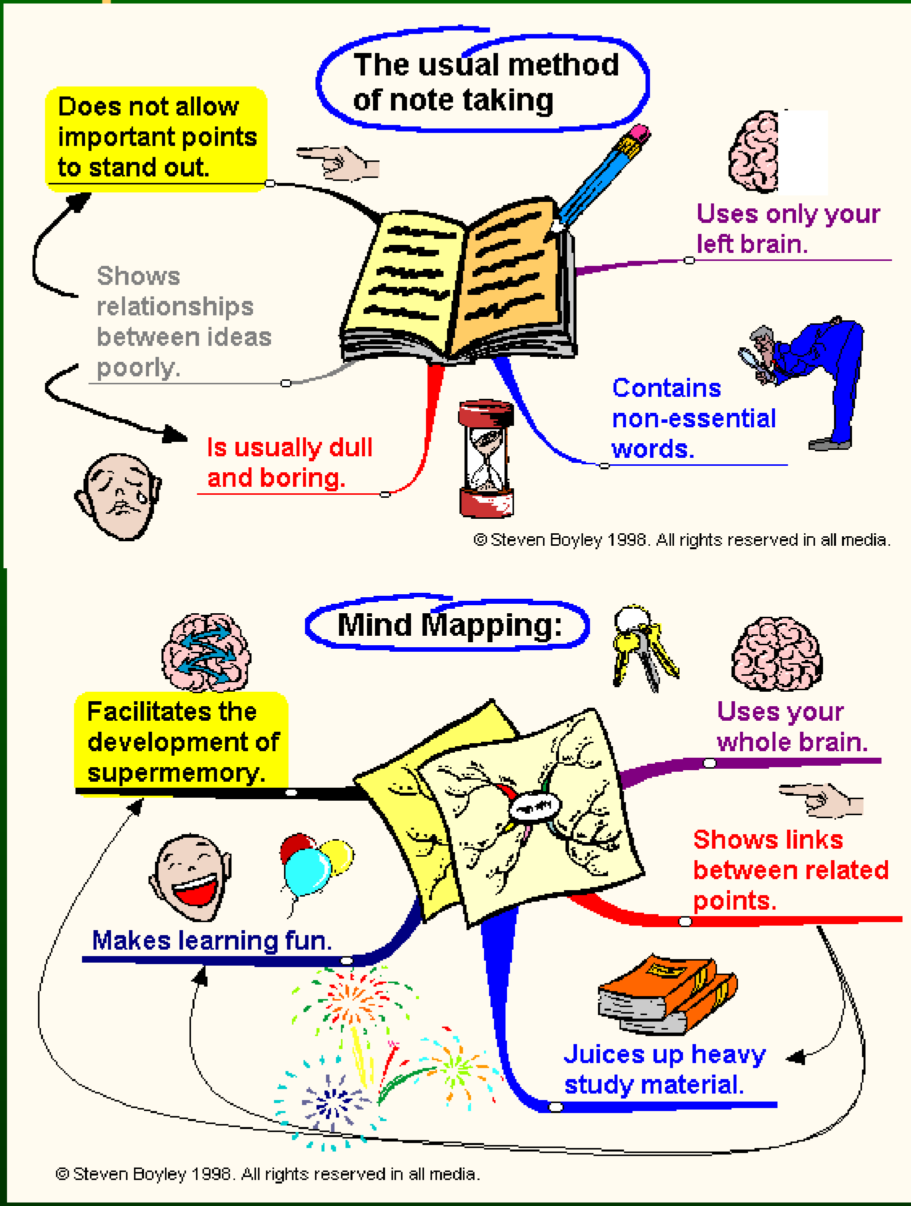
Brain maps

Best: organize info like in the brain of an expert.

- Many books on mind maps.
- Many software packages.

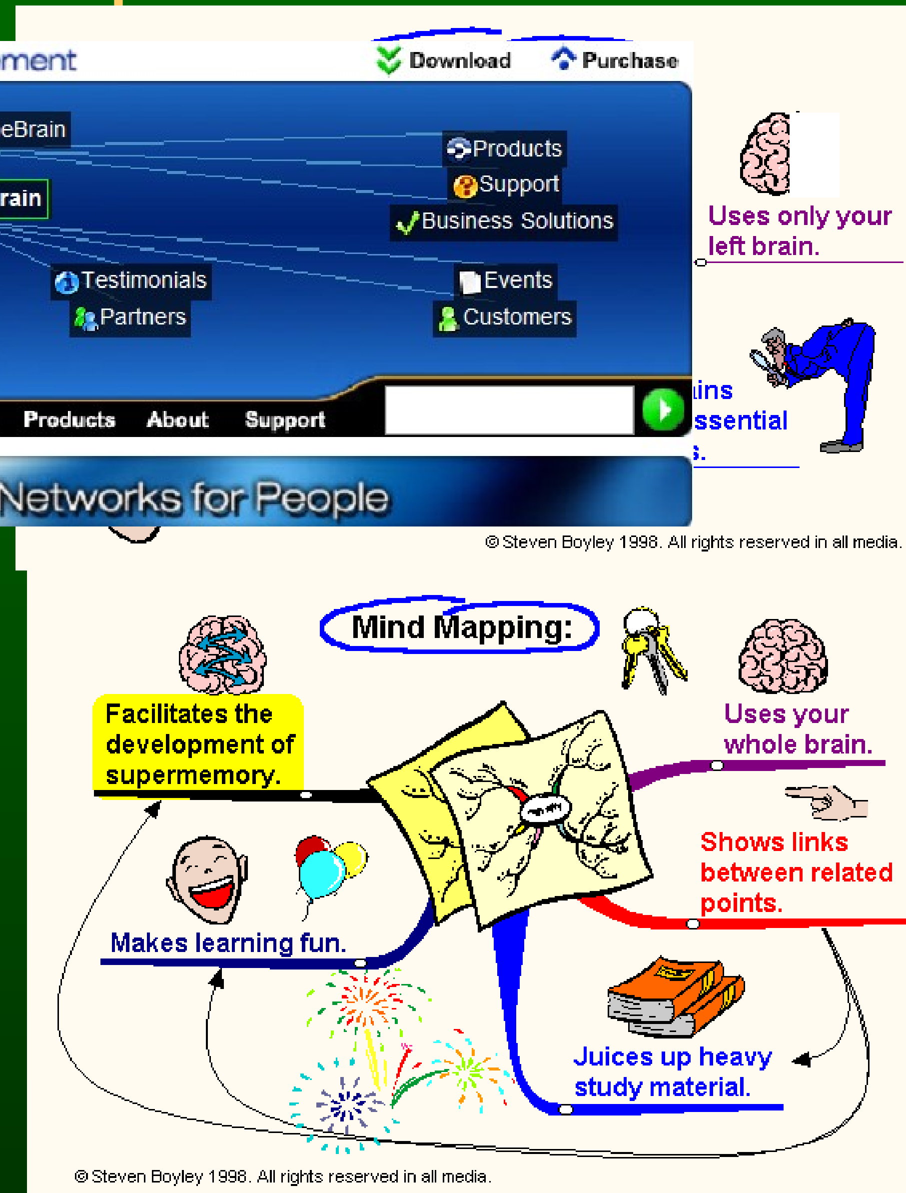
- TheBrain (www.thebrain.com) interface making hierarchical maps of Internet links.

- Other software for graphical representation of info.
- Our implementation (Szymanski): Wordnet, Wikipedia graphs extension to similarity is coming.



Brain maps

of Internet links.



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extension to similarity is coming.

Neuroeducation

As educators you are sculpting brains!

Pedagogy has developed through trial and error, now technology that shows how experience and teaching creates pathways in the brain already exists.

Neuroeducation:
interdisciplinary field that connects many branches of science, including pedagogy, psychology, neuroscience and informatics to understand information flow in the brain and create effective ways of teaching.

H.H. Donaldson wrote „The Growth of the Brain: A Study of the Nervous System in Relation to Education”, in 1895!

R.P. Halleck, The Education of the Central Nervous System: A Study of Foundations, Sensory and Motor Training, 1896!

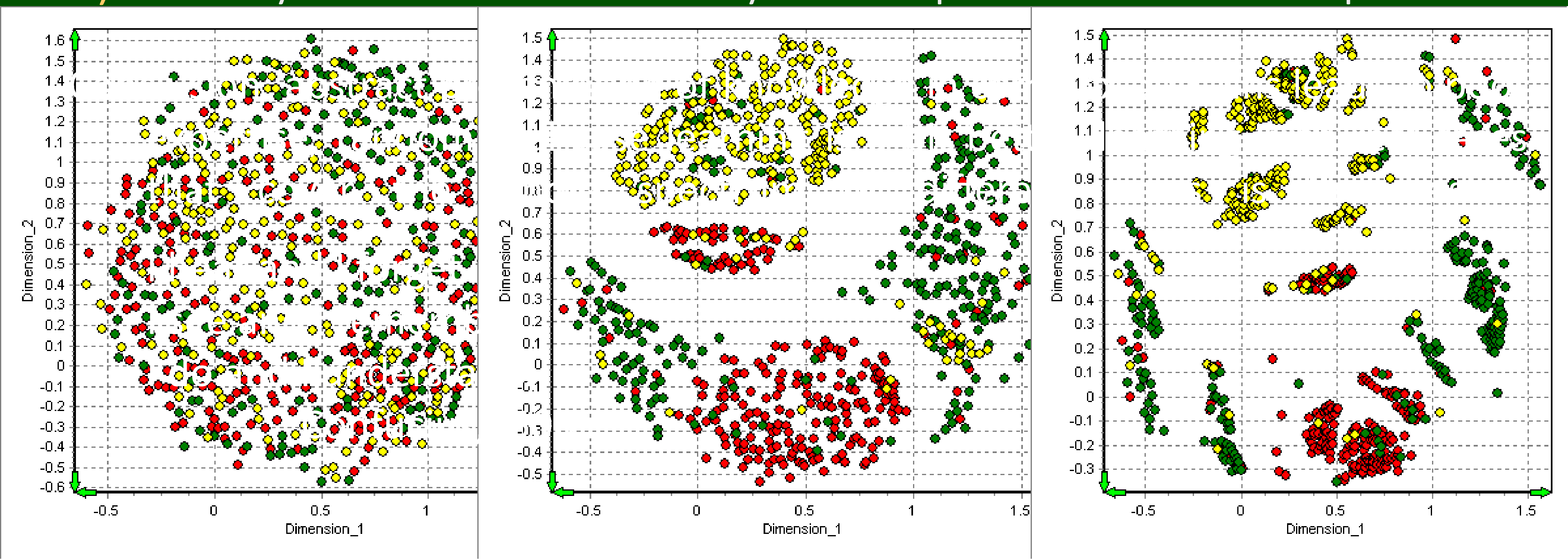
How to become an expert?

Textbook knowledge in medicine: detailed description of all possibilities.

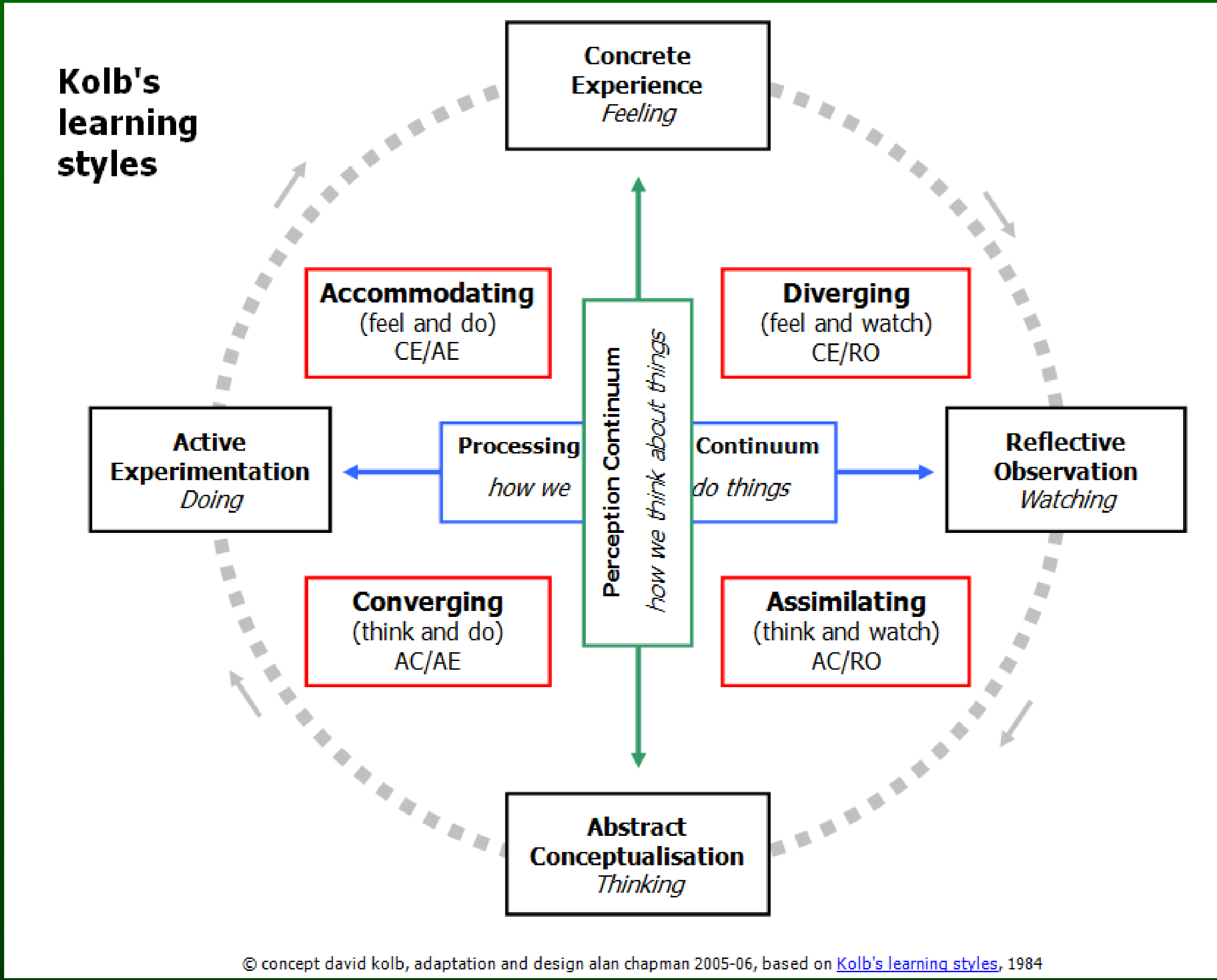
Effect: neural activation flows everywhere and correct diagnosis is impossible. Correlations between observations forming prototypes are not firmly established. Expert has only correct, “intuitive” associations; deep attractors = .

Example: 3 diseases, vector NLP on clinical case description, MDS visualization.

1) System that has been trained on textbook knowledge: weak attractors.
2) Same system that has learned later on real cases: deeper attr, still connected.
3) Same system that has learned only on description of real cases: deep attr.



Learning styles



David Kolb, *Experiential learning: Experience as the source of learning and development* (1984), and *Learning Styles Inventory*.

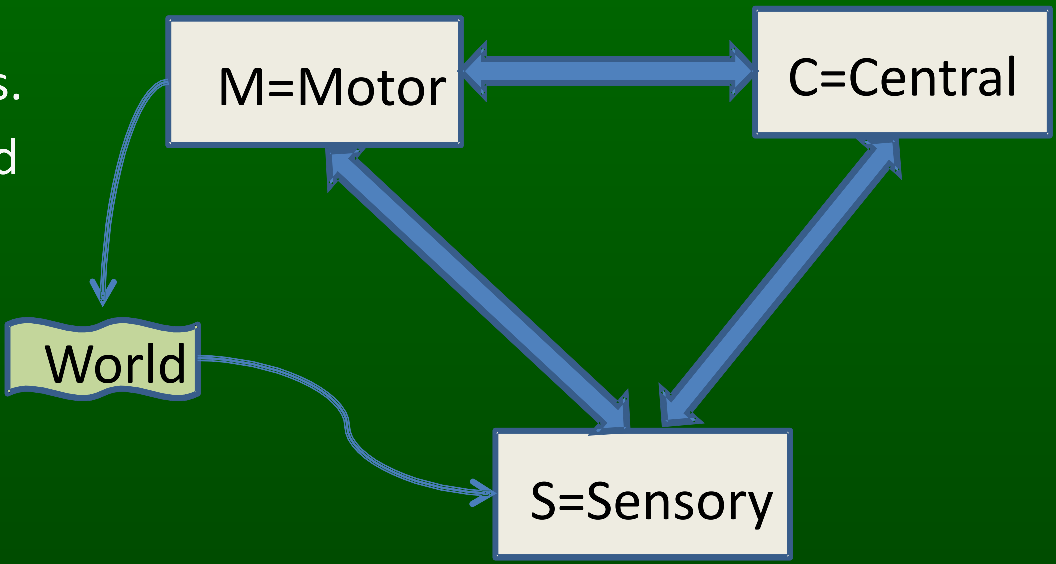
Connectome and learning styles

Simple connectome models may help to connect and improve learning classification of the styles.

S, Sensory level, occipital, STS, and somatosensory cortex;

C, central associative level, abstract concepts that have no sensory components,

mostly parietal, temporal and prefrontal lobes.



M, motor cortex, motor imagery & physical action.
Frontal cortex, basal ganglia.

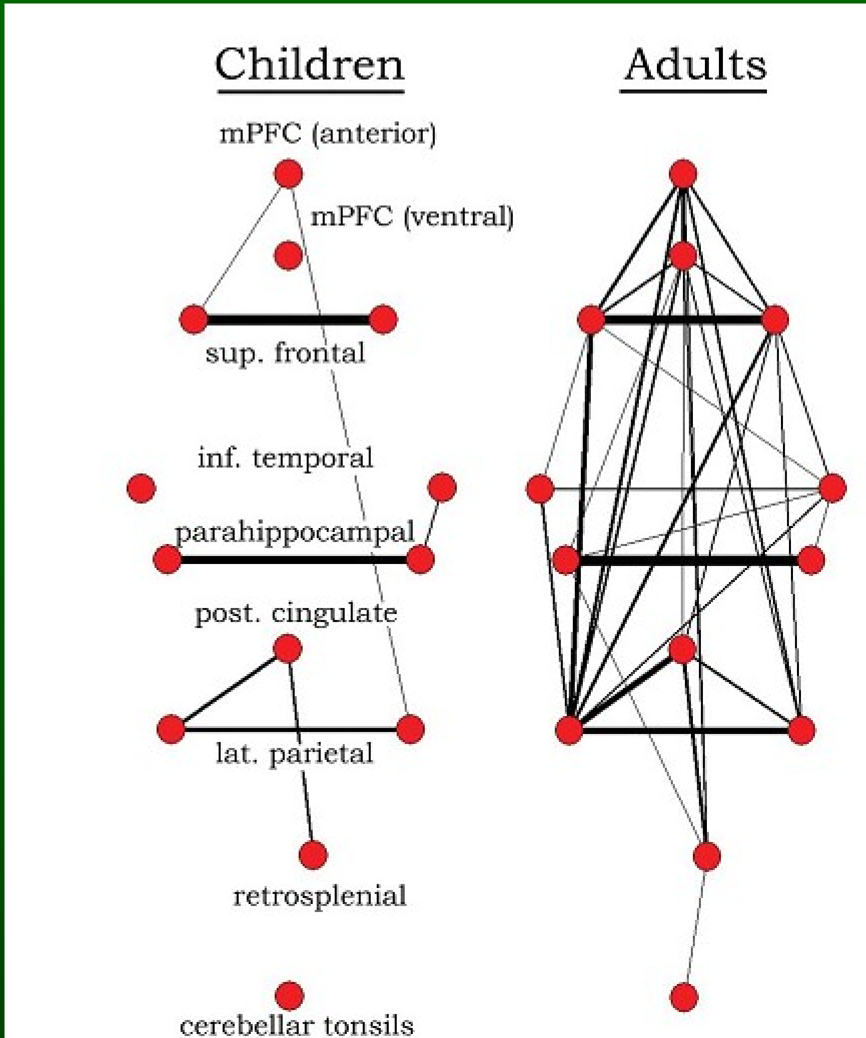
Even without emotion and reward system predominance of activity within or between these areas explains many learning phenomena.

Origin of the learning styles

Connectomes develops before birth and in the first years of life.

Achieving harmonious development is very difficult and depends on low-level (genetic, epigenetic, signaling pathways) processes, but may be influenced by experience and learning.

- Excess of low-level (sensory) processes S⇔S.
- Poor C⇔C neural connections and synchronization, frontal⇔parietal necessary for abstract thinking, weak functional connections prefrontal lobe ⇔ other areas.
- Patterns of activation in the brain differ depending on whether the brain is doing social or nonsocial tasks.
- “Default brain network” involves a large-scale brain network (cingulate cortex, mPFC, lateral PC), shows low activity for goal-related actions; strong activity in social and emotional processing, mindwandering, daydreaming.



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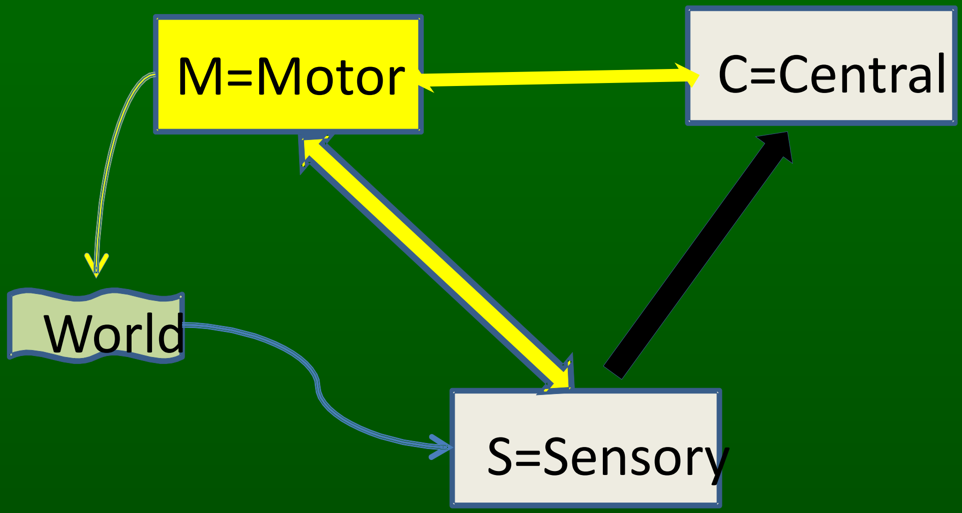
Learning styles D1

Kolb passive-active dimension, observation – experimentation: motor-central processes M⇔C, sensory-motor processes M⇔S.

Autistic people: processes at the motor level M⇔M, leads to repetitive movements, echolalia.

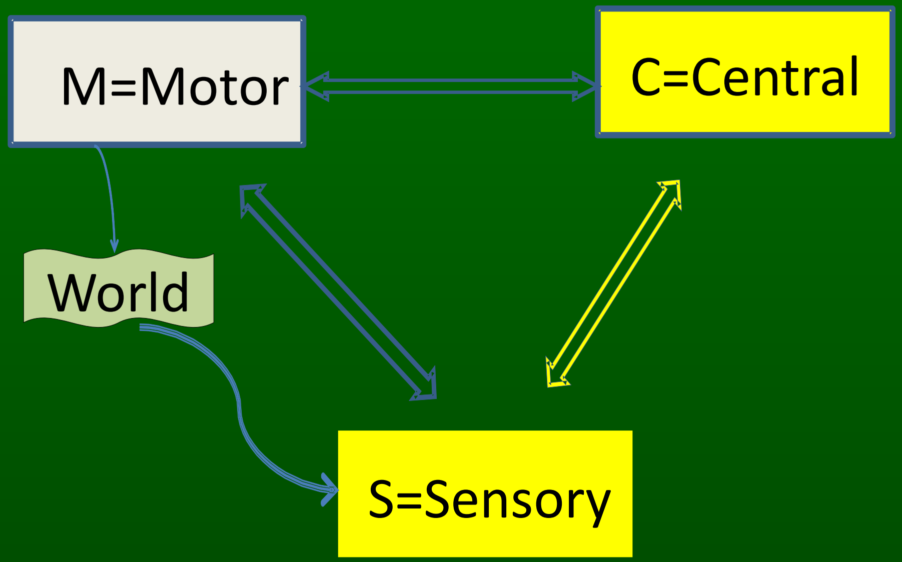


The *Learning Styles Inventory* is a tool to determine learning style. The tool divides people into 4 types of learners:

- divergers (concrete, reflective),
- assimilators (abstract, reflective),
- convergers (abstract, active),
- accommodators (concrete, active).

Learning styles D2

Kolb perception-abstraction:
coupling within sensory S⇔S areas, vs.
coupling within central C⇔C areas.



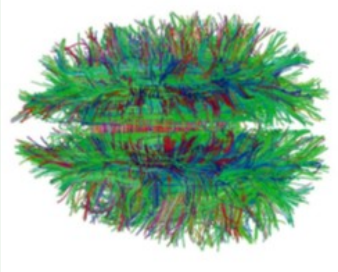
Strong C=>S leads to vivid imagery dominated by sensory experience.

Autism: vivid detailed imagery,
no generalization.

Attention = synchronization of neurons, limited to S, perception S⇔S strongly binds attention => no chance for normal development.
Asperger syndrome strong C=>S activates sensory cortices preventing understanding of metaphoric language.

If central C⇔C processes dominate, no vivid imagery but efficient abstract thinking is expected - mathematicians, logicians, theoretical physicist, theologians and philosophers ideas.

4 styles and more



Assimilators think and watch: prone to abstract thinking, reflective observation, inductive reasoning due to strong connections S=>C and within C⇔C, weak connections from S=>M and C=>M.

Convergers combine abstract conceptualization, active experimentation, using deductive reasoning in problem solving.
Strong C⇔C and C=>M flow of activity.

Divergers focus on concrete experience S⇔S, strong C⇔S connections and C⇔C activity facilitating reflective observation, strong imagery, novel ideas but weak motor activity.

Accommodators have balanced sensory, motor and central processes and thus combine concrete experience with active experimentation supported by central processes S⇔C⇔M.

The idea of learning styles is criticized because there was no theoretical framework behind it, but objective tests of the learning styles may be based on brain activity.

Memes and neurons

Richard Dawkins introduced memes in 1976.
Meme is a unit for carrying cultural ideas, symbols, or practices that can be transmitted from one mind to another through writing, speech, gestures, rituals, any imitable phenomena.

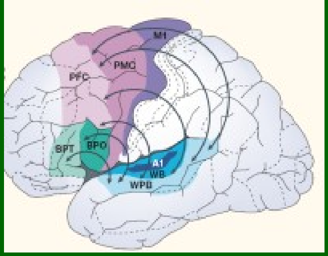
The **Journal of Memetics** was launched in 1997 and closed in 2005. In science the concept of memes has never been linked to brain processes.

Memes are much less stable then genes, embedding themselves in brain functional connectivity, creating strong attractors of neurodynamics.

Formation of memes, evolutionary processes, and creativity are linked.
D.T. Campbell (1960) has described general theory of creativity based on blind (non-teleological) variations followed by selective retention, hence BVSR.

Neural foundations of memetics are worth developing.

Creativity with words



The simplest testable model of creativity (~ Campbell BVSR):

- create interesting novel words that capture some features of products;
- understand new words that cannot be found in the dictionary.

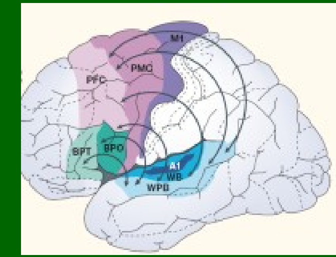
Model inspired by the putative brain processes when new words are being invented starting from some keywords priming auditory cortex.

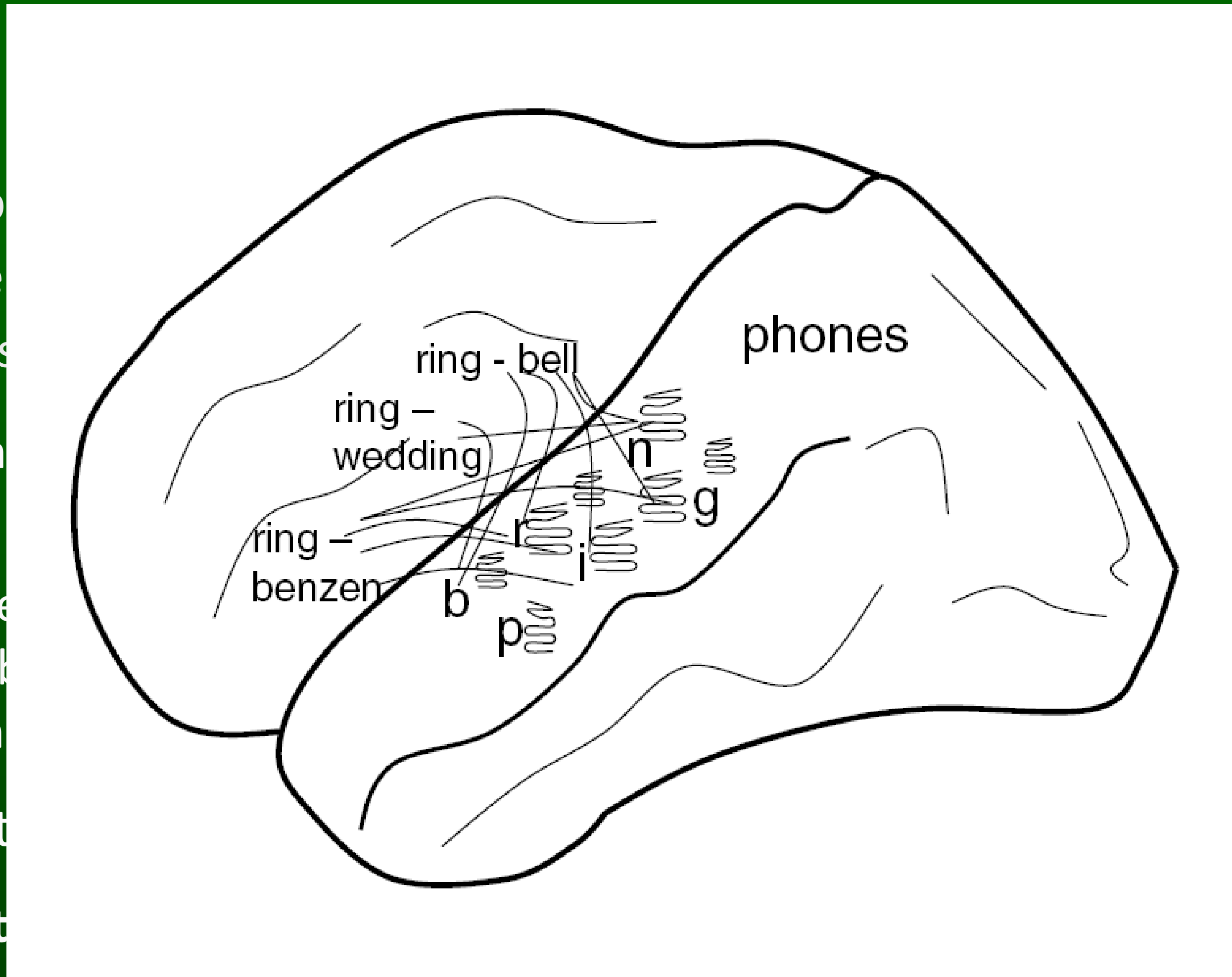
Phonemes (allophones) are resonances, ordered activation of phonemes will activate both known words as well as their combinations; context + inhibition in the winner-takes-most leaves only a few candidate words.

Creativity = network+imagination (fluctuations)+filtering (competition)

Imagination: chains of phonemes activate both word and non-word representations, depending on the strength of the synaptic connections. **Filtering**: based on associations, emotions, phonological/semantic density.

discoverity = {disc, disco, discover, verity} (discovery, creativity, verity)
digventure ={dig, digital, venture, adventure}   new!
Visual: Google Deep Dream hallucinations – but video streams not natural.





The simp

- create … oducts;
- unders

Model in … re being
invented

Phoneme … emes will
activate … + inhibition in
the winn

Creativit … npetition)

Imaginat … d
representations, depending on the strength of the synaptic connections. **Filtering**: based on associations, emotions, phonological/semantic density.

discoverity = {disc, disco, discover, verity} (discovery, creativity, verity)
digventure ={dig, digital, venture, adventure}   new!
Visual: Google Deep Dream hallucinations – but video streams not natural.

Conspiracy in the brain

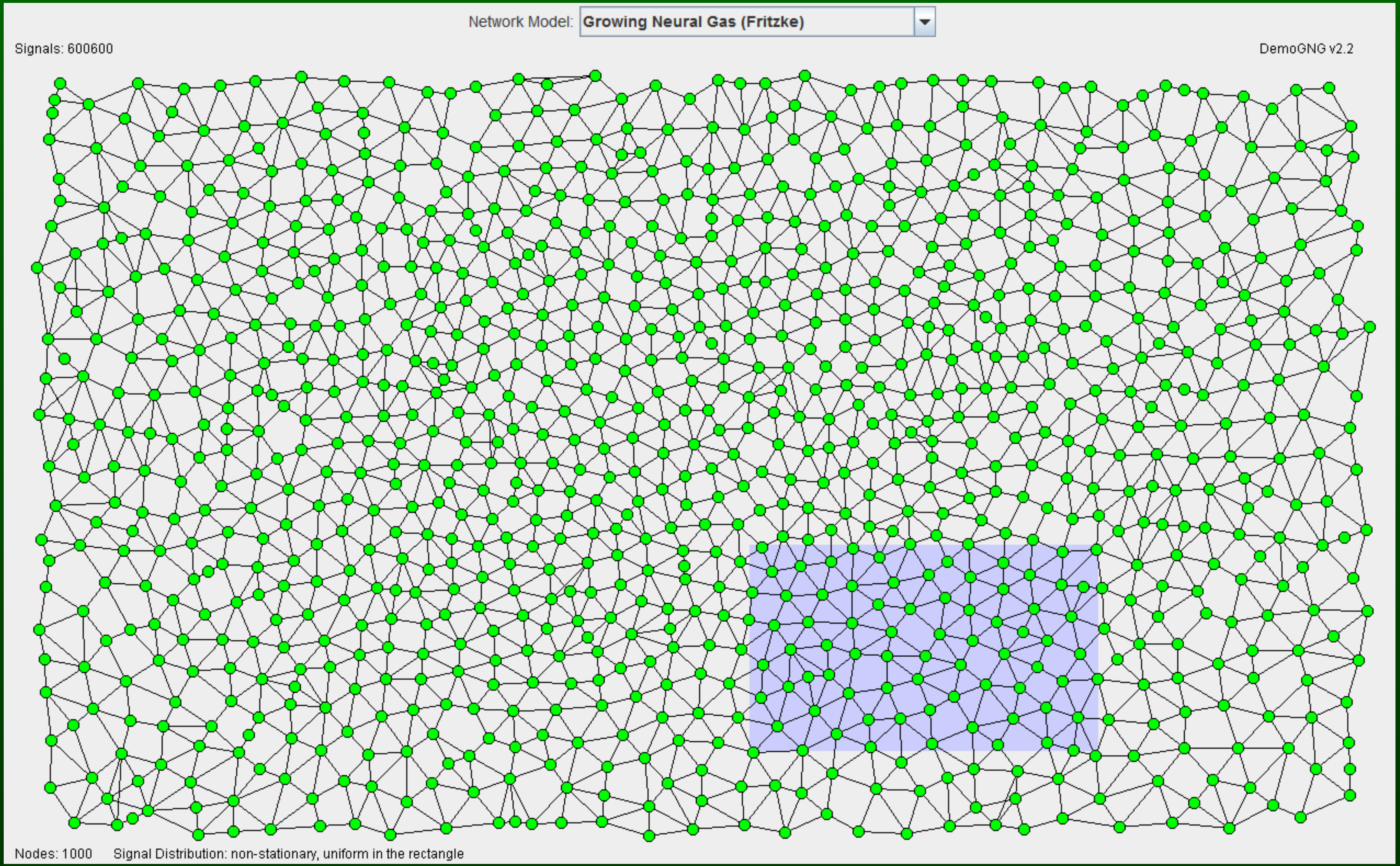
The soul selects its own society, then shuts the door. Emily Dickinson.
Slow and rapid scenarios are possible, here only rapid presented:

- Emotional situations => neurotransmitters => neuroplasticity => fast learning, must be important.
- Fast learning => high probability of wrong interpretation.
- Traumatic experiences, hopelessness, decrease brain plasticity and leave only strongest association – strongly connected pathways.
- Conspiracy theories form around such associations, "frozen" pathways lead to brain activations forming strong attractors, distorting rational thinking.
- Such strong associations save brain energy and cannot be changed by rational arguments, that influence weaker associations only.
- This explanation becomes so obviously obvious …

Model: concept vectors derived from a corpus + MDS or Growing Neural Gas visualization (Martinetz & Schulten, 1991).

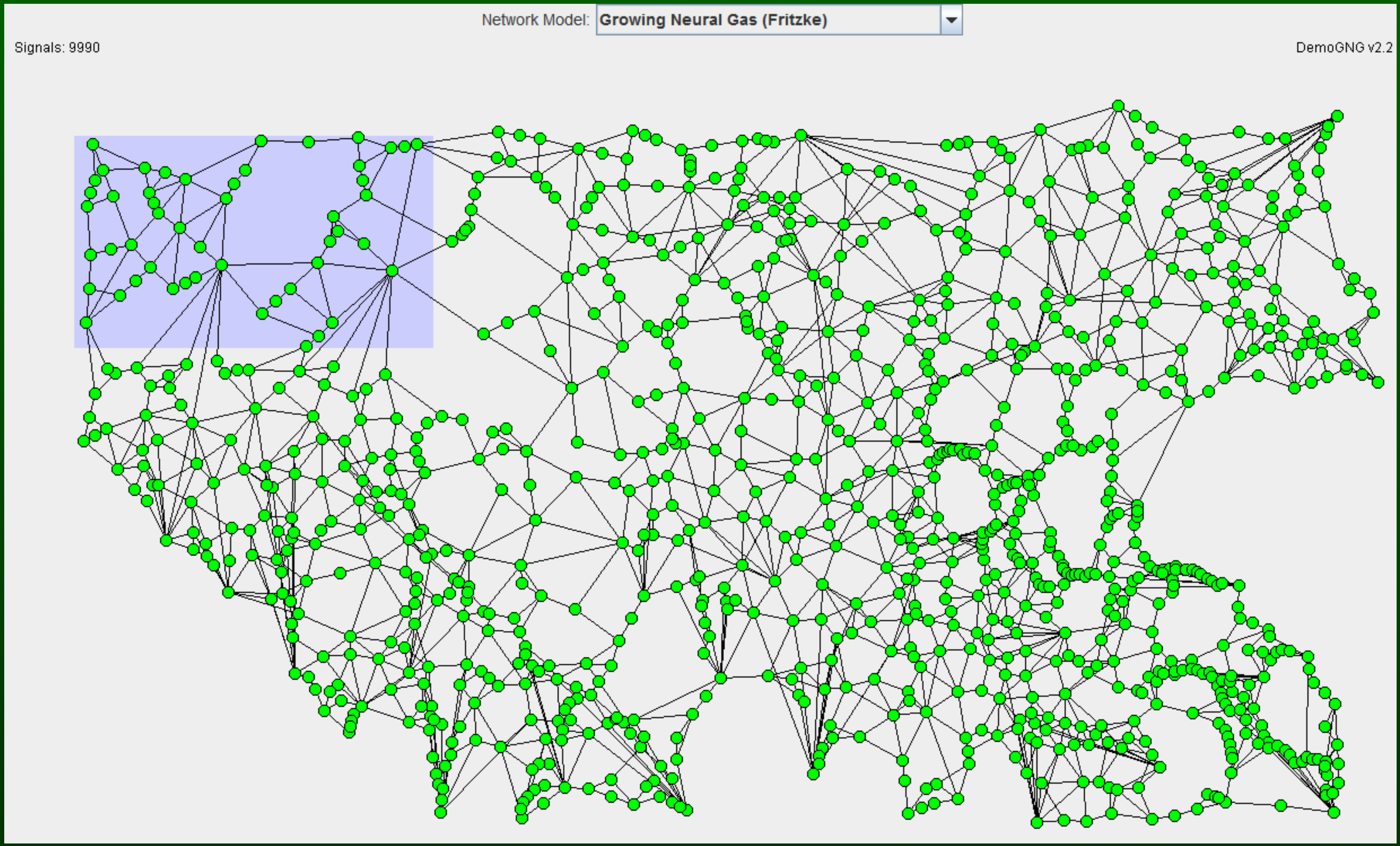
Internalization of environment

Episodes are remembered and serve as reference points, if observations are unbiased they reflect reality, creating correct associations.



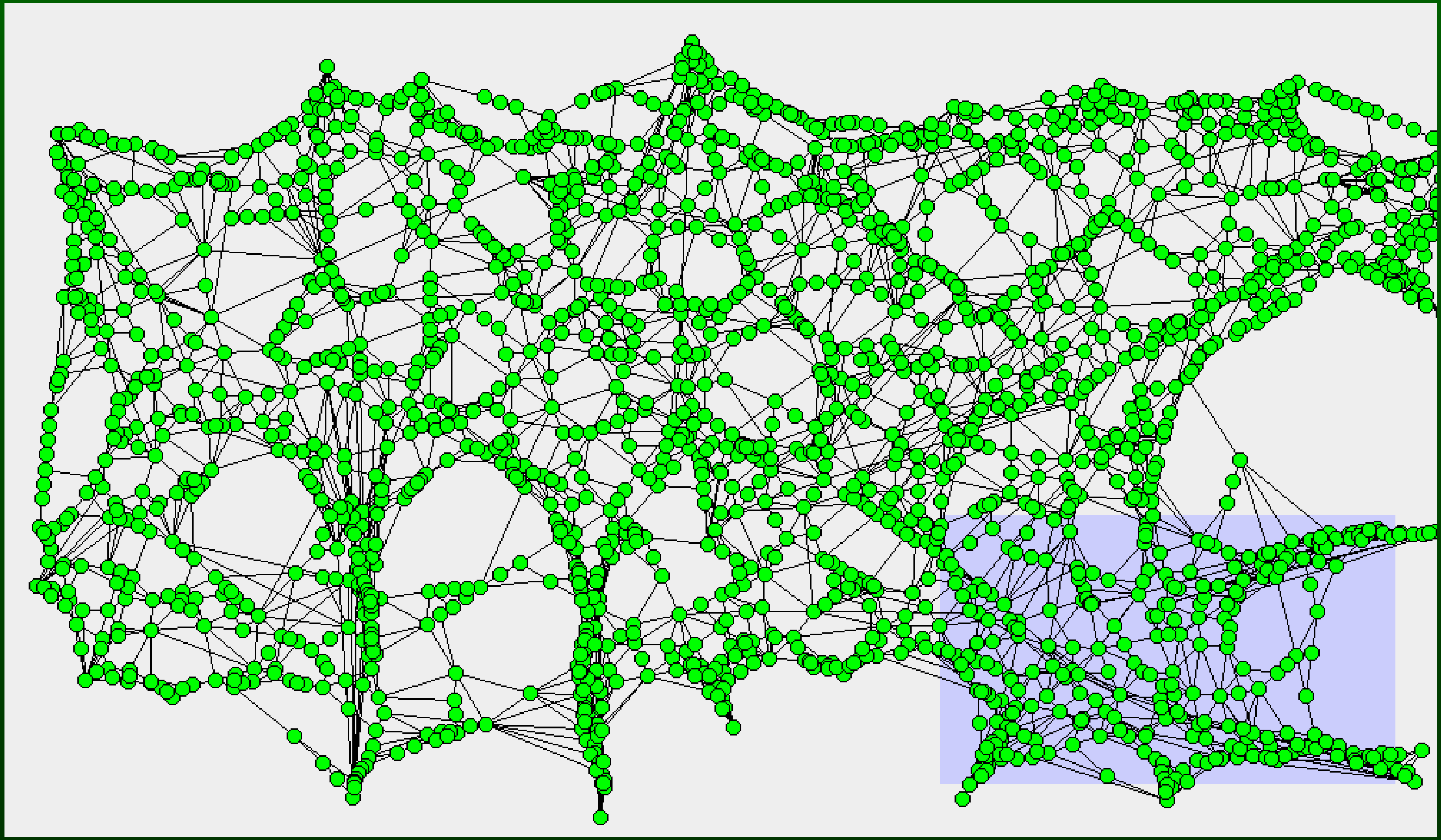
Extreme plasticity

Brain plasticity (learning) is increased if long, Slow strong emotions are involved. Followed by depressive mood it leads to severe distortions, false associations, simplistic understanding.



Conspiracy views

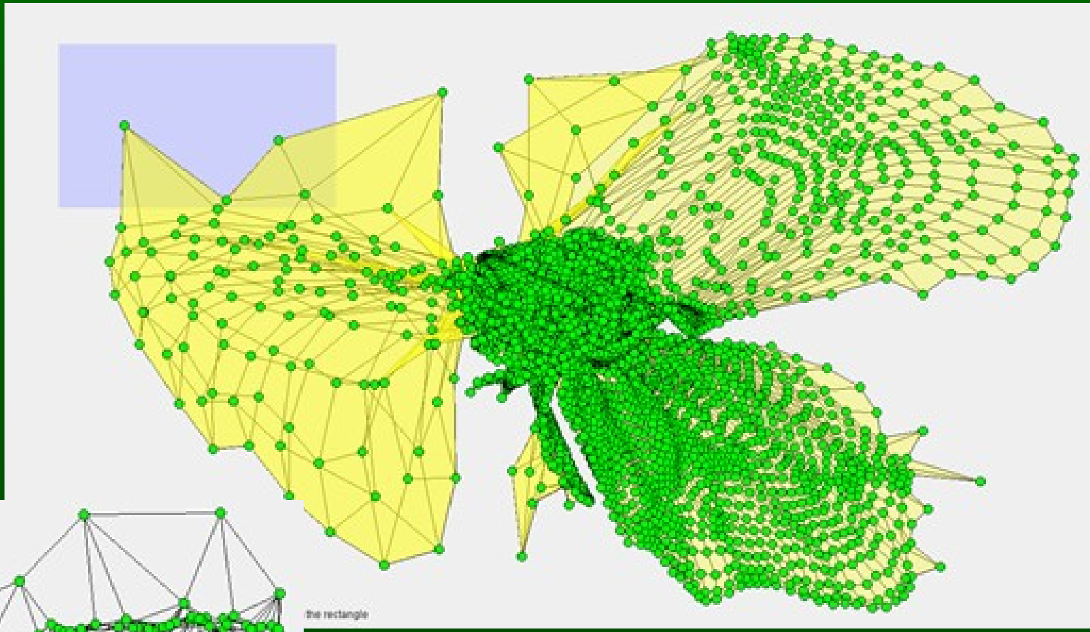
Illuminati, masons, Jews, UFOs, or twisted view of the world leaves big holes and admits simple explanations that save mental energy, creating „sinks" that attract many unrelated episodes.

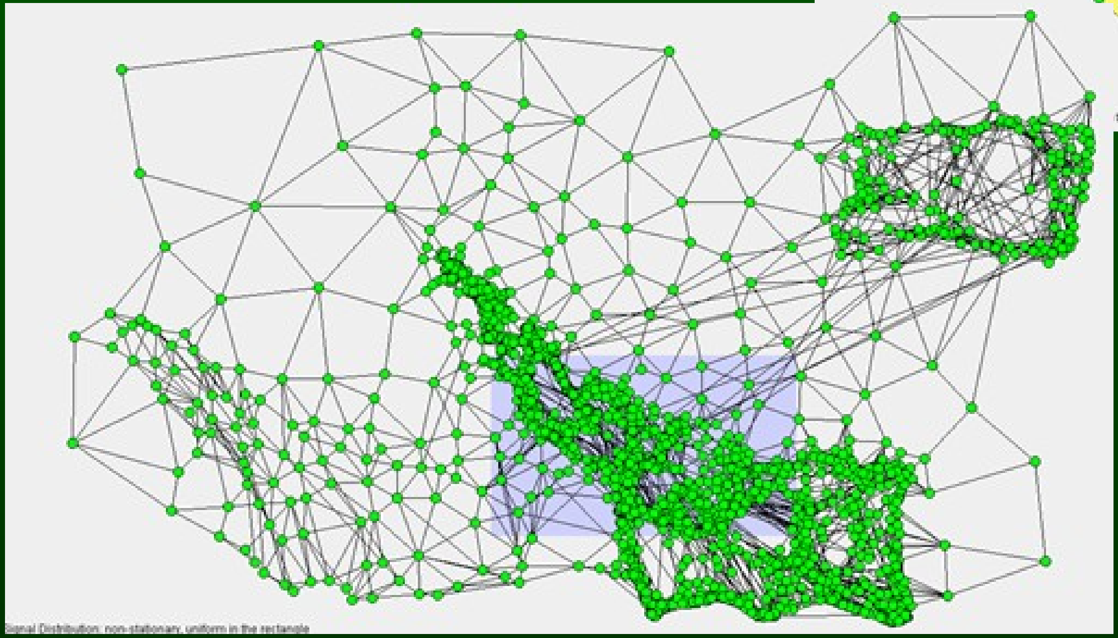


Memoids …

Totally distorted world view, mental processes are reduced to a memplex …

Ready to sacrifice oneself for a great idea.

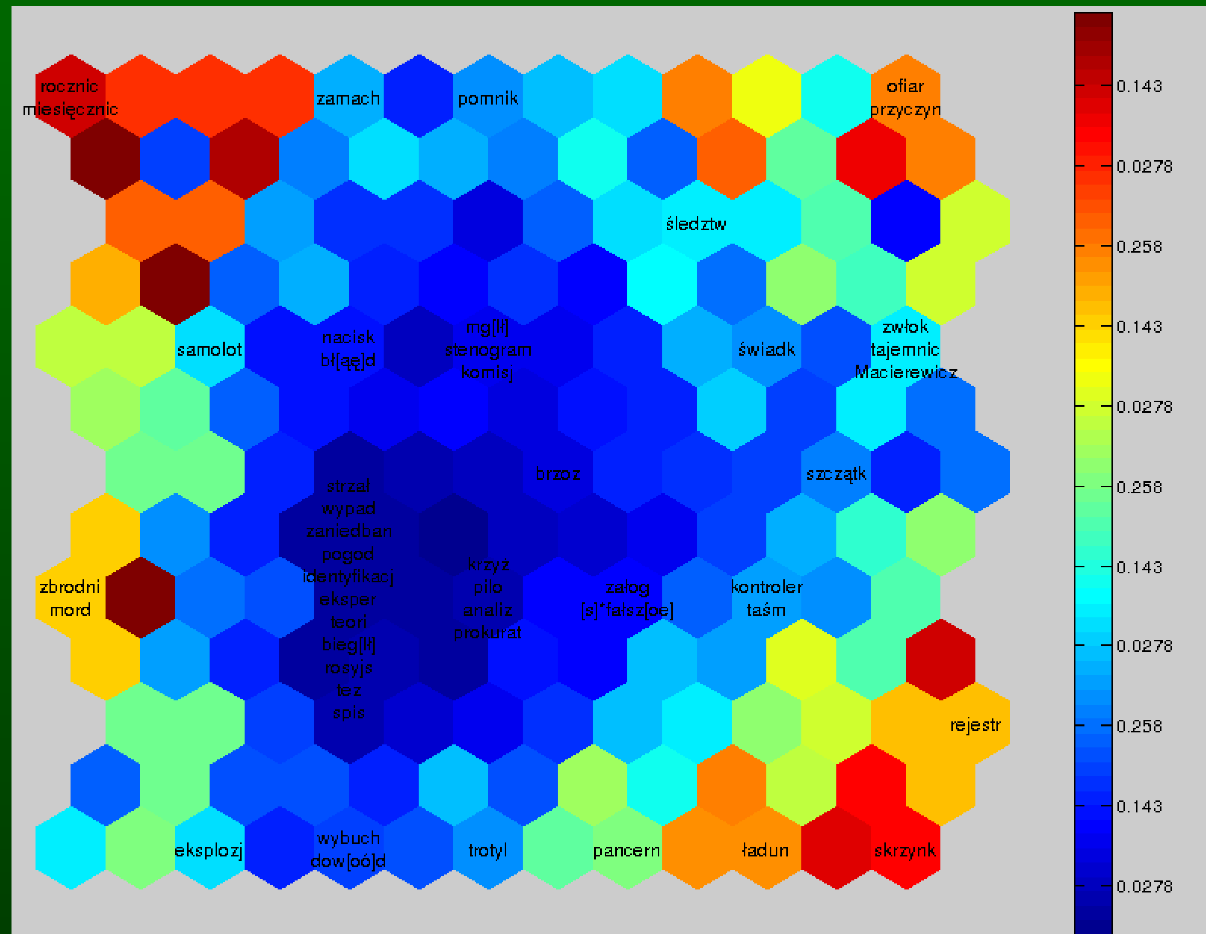




SOM on real newspaper data

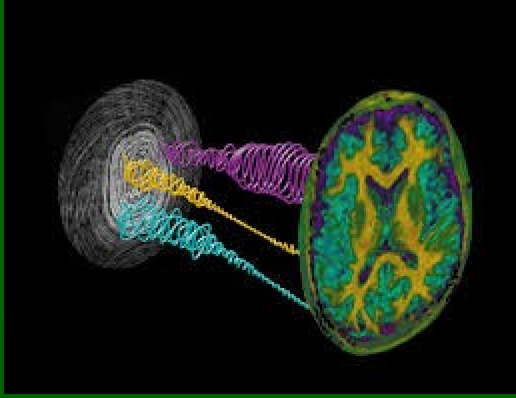
Different groups of people read different newspapers, are exposed to different media and social networks, resulting in different network of concepts and sharp polarization of opinions.

Big sinks attract neurodynamics manifesting in strong automatic associations with core concepts.



Different associative networks make communication almost impossible.
Work in progress (with J. Szymanski et al.)

Shared concepts



Concepts activate brains facilitating segmentation of experience, categorizing and simplifying observations.
Without concepts self-reflection is not possible, associations will not allow for inferences and systematic planning.

Shared space of concepts is needed for mutual understanding, communication.
This is possible because human brains have similar structural connectivity.
It is difficult because functional connectivity is different, as a result of diverse cultural codes.

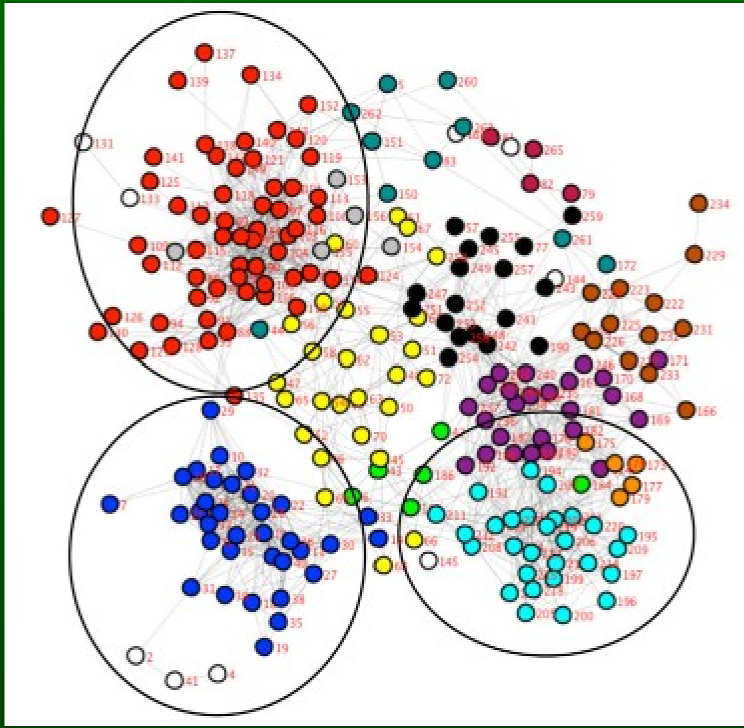
Since 1986 in the USA and UK Core Knowledge Foundation tries to define common cultural codes, from preschool to the end of primary school, in precise sequence. Their motto: knowledge builds on knowledge.

Communication space: how do we understand concepts, associate them, how my conceptual network differs from yours, and how should I effectively communicate my views and ideas to you?

Common model space

How to compare activations of different brains to bring them into resonance?

Guntupalli et al, A Model of Representational Spaces in Human Cortex. Cerebral Cortex (2016).

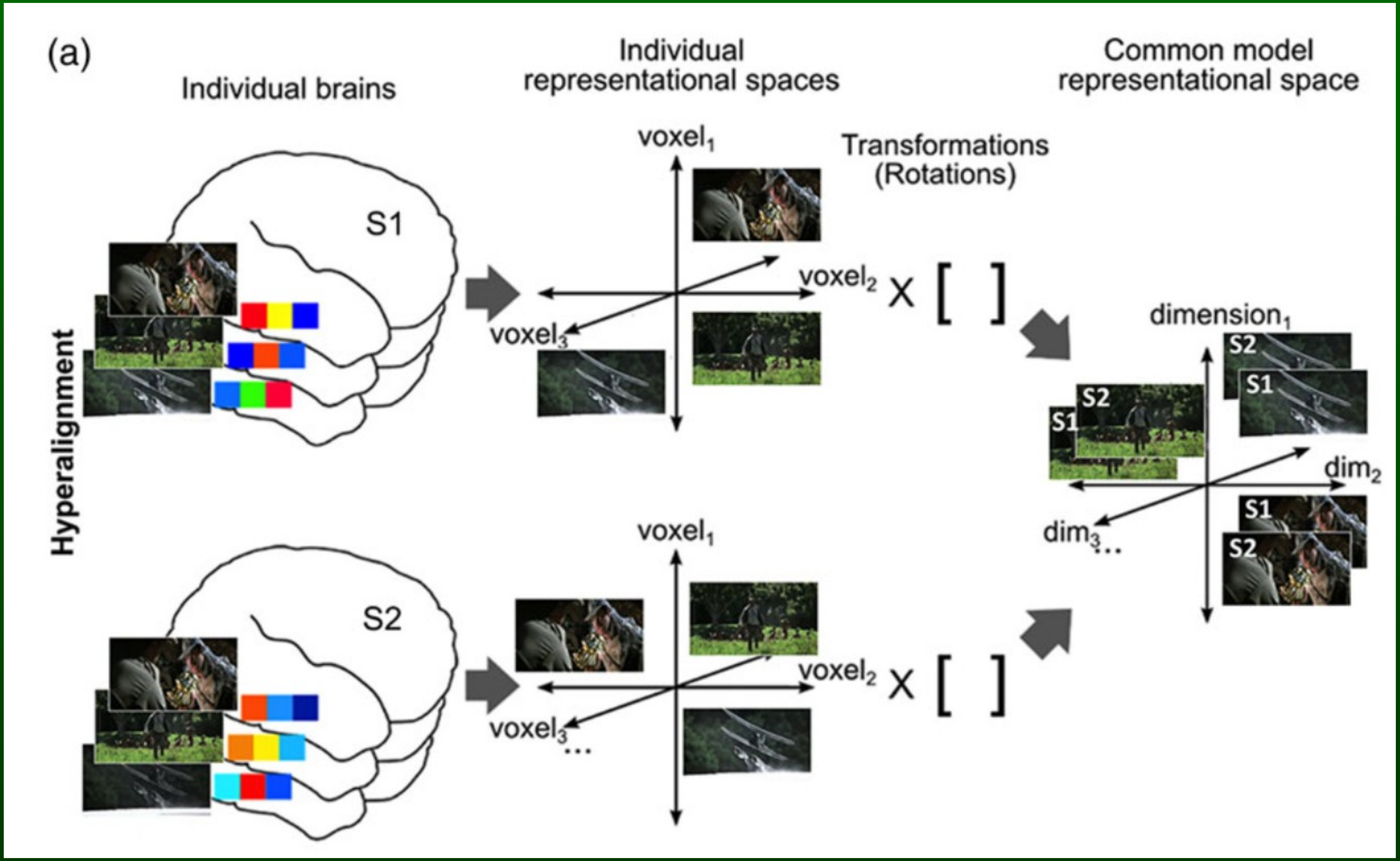


"Searchlight hyperalignment" algorithm to define common model space for the whole cortex.

The model aligns representations of complex, dynamic stimuli across brains in occipital, temporal, parietal, and prefrontal cortices, as shown by between-subject multivariate pattern classification and intersubject correlation of representational geometry, indicating that structural principles for shared neural representations apply across widely divergent domains of information. The model provides a rigorous account for individual variability of well-known coarse-scale topographies, such as retinotopy and category selectivity, and goes further to account for fine-scale patterns that are multiplexed with coarse-scale topographies and carry finer distinctions.

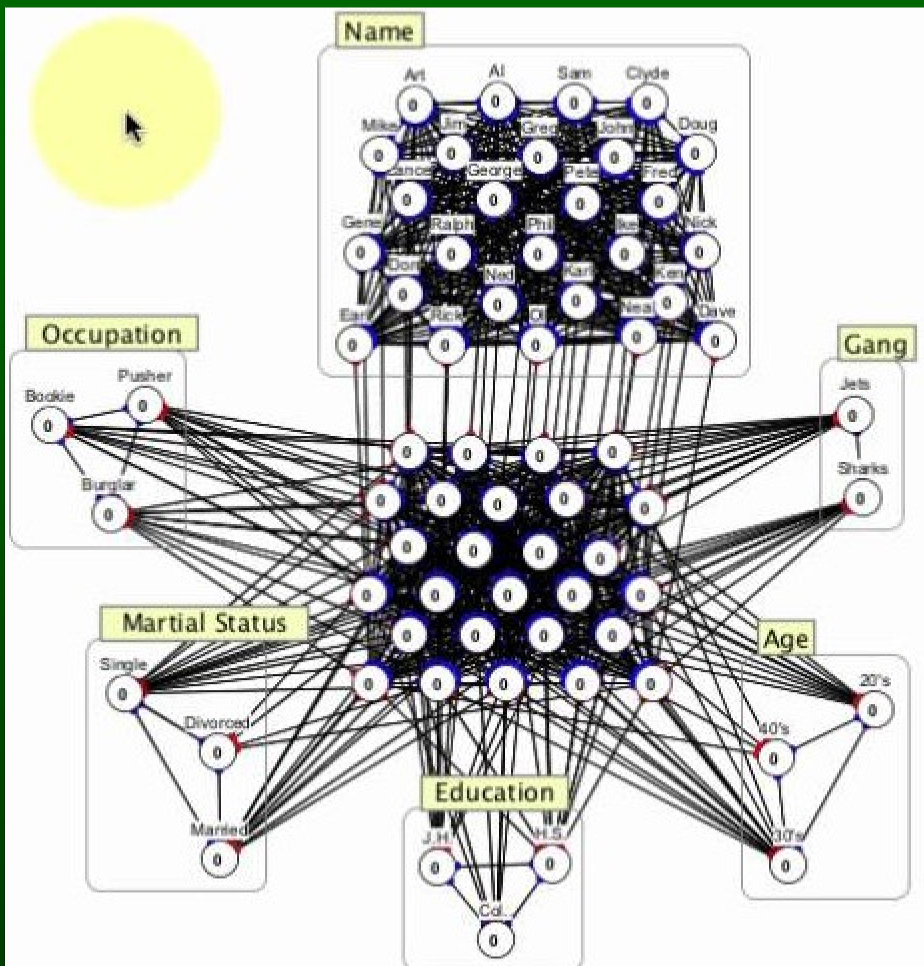
Hyperalignment

How to compare activations of different brains to bring them into resonance?



Resonance for communication

Mapping between two conceptual frameworks.



Jets/Sharks IAT net (McClleland 1981).

How will my words resonate in another brain?

That depends on the network of activations that represent concepts in both brains.

Unless we share common history this resonance is

Spreading activation in common model space should allow to find mapping between two brains and help to establish similar processes in artificial neural networks.

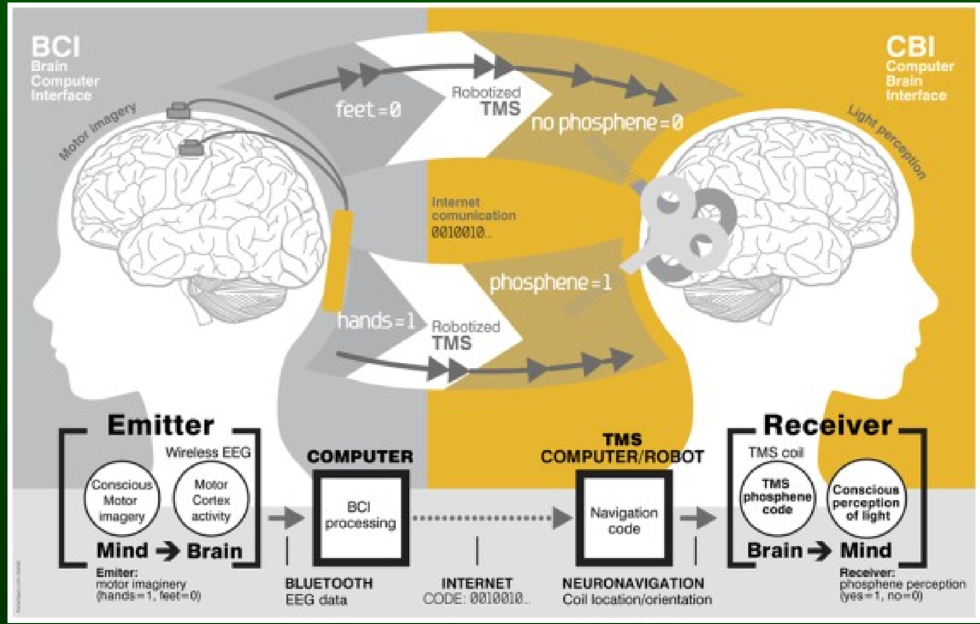
Direct brain activation

Sony patent for direct streaming of multimedia to the brain.

Method and system for generating sensory data onto the human neural cortex.
US Patent 6536440 B1

It should enable “sensory experiences” by firing “pulses of ultrasound at the head to modify firing patterns in targeted parts of the brain.”
This would allow the device to trigger various senses, including taste and sound, and even allow the deaf to hear again.

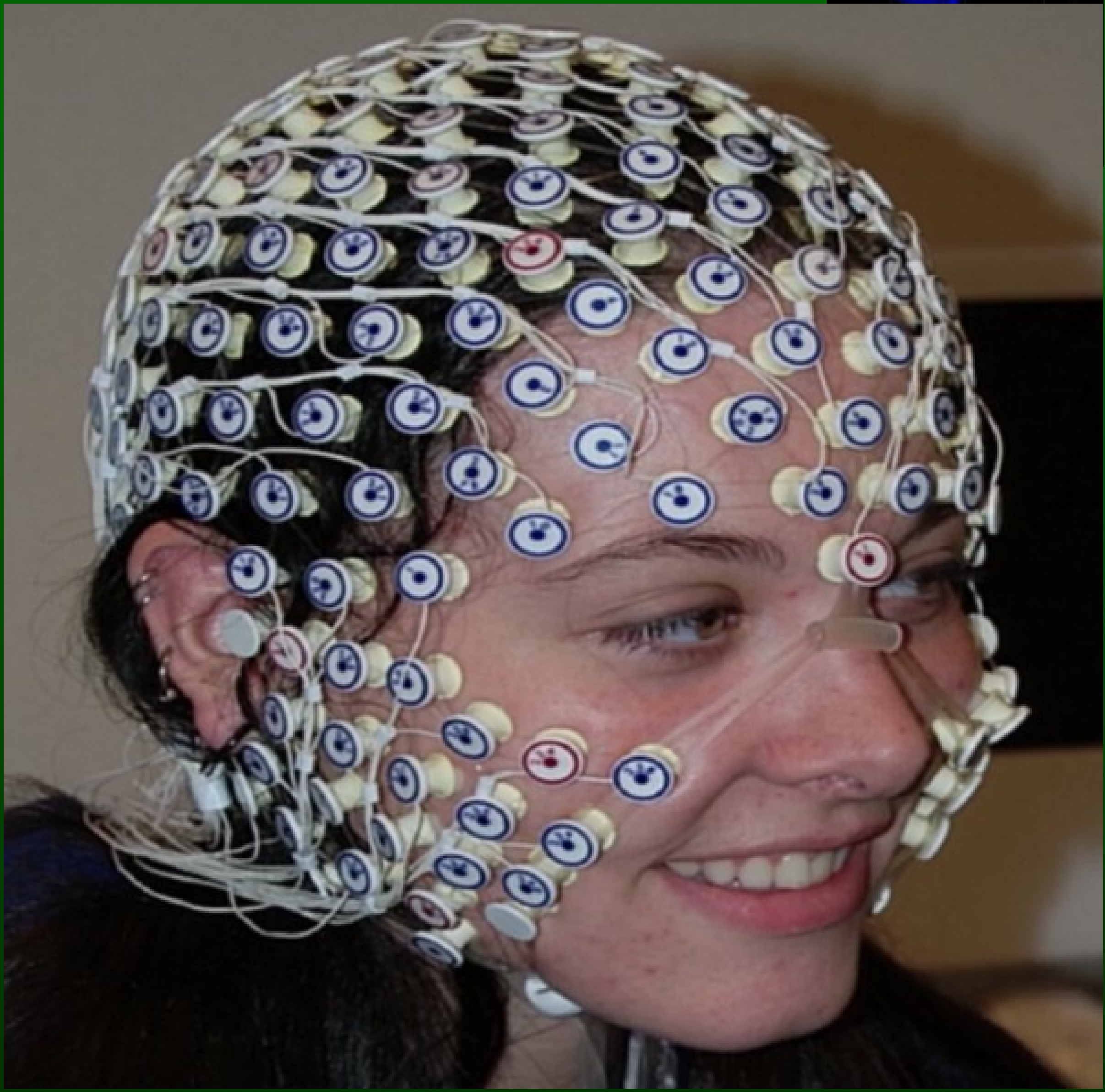
Facilitating Brain-to-Brain Communication ?



Resonance through HD DCS?

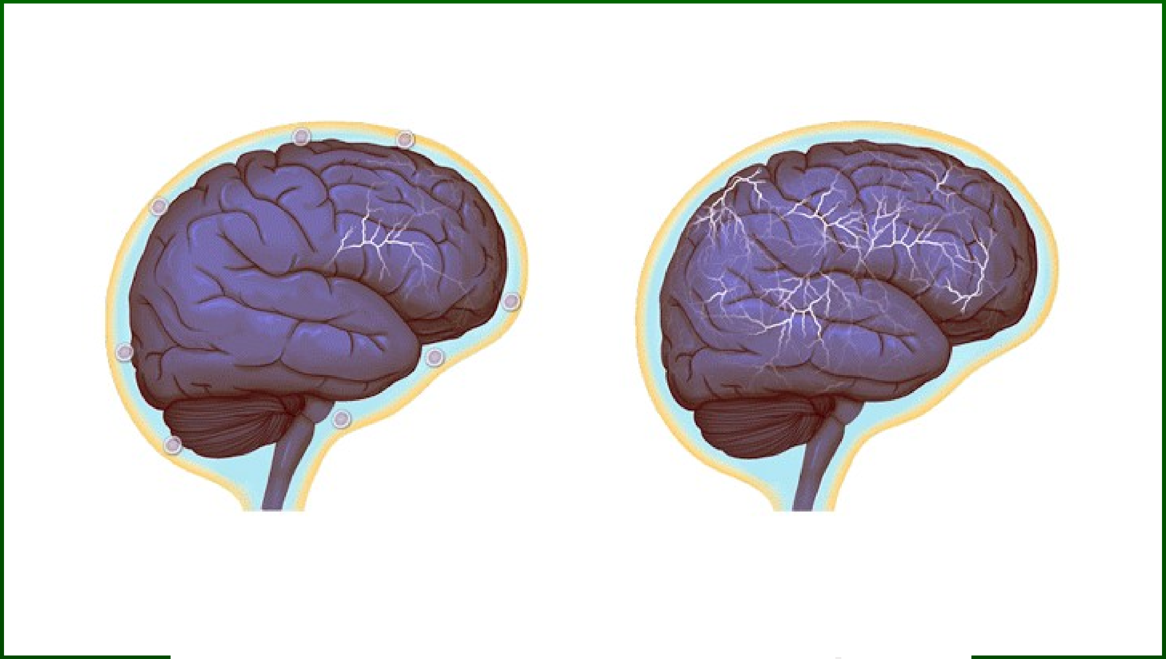
Reading brain states => transforming to common space => duplicating in other brains … Depression, neuro-plasticity, teaching!

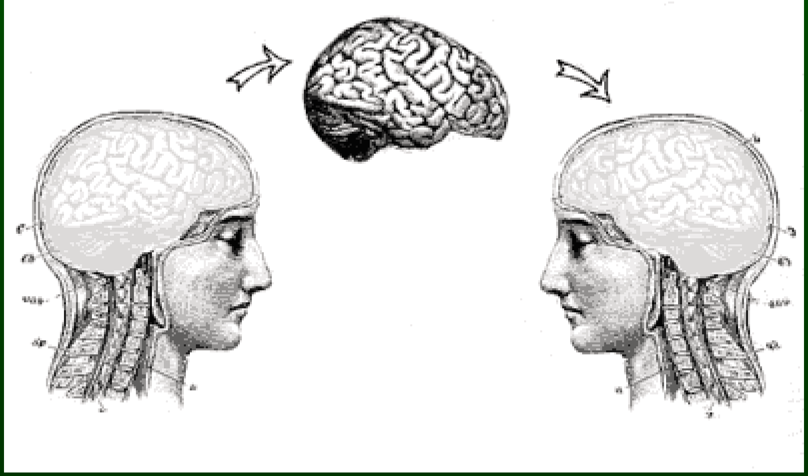
Multielectrode DCS stimulation with 256 electrodes induces changes in the brain increasing neuroplasticity.



Resonance through HD DCS?

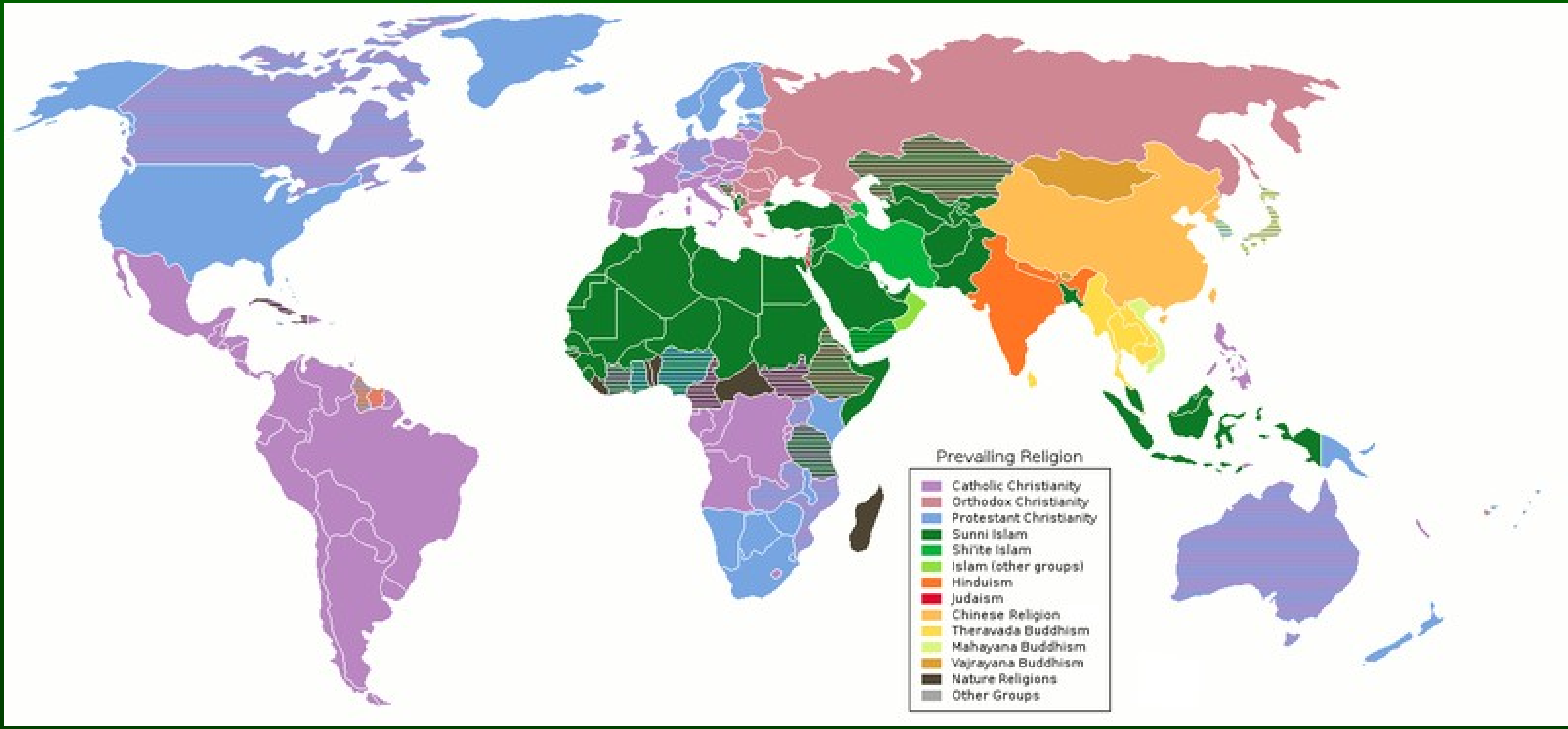
Reading brain states => transforming => recreating.





Dimensions of Human Experience

How do we understand ourselves, what is the vision of human nature across time, geographical location and subculture?



Is there a common space for communication in times of social media? Everyone can hide in his/her own niche.

Conclusions

Grand challenges are facing us
at every level!

Neurodynamics and neurocognitive phenomics
is the key to understand cognitive communication.

Is there a shorter route
to understand human behavior?

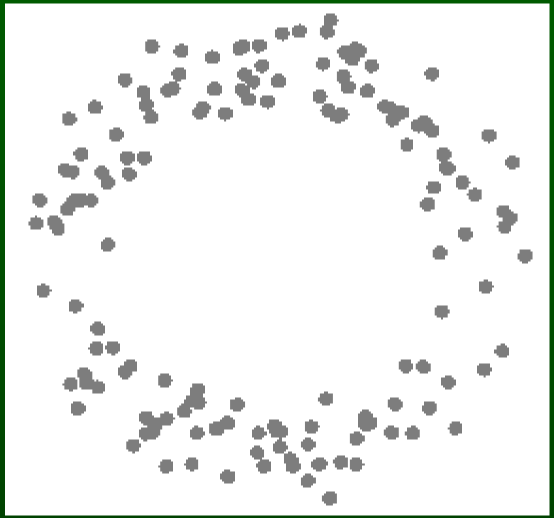
I do not think so …

Duch W, *Brains and Education: Towards Neurocognitive Phenomics* (2013)

Soul or brain: what makes us human?
Interdisciplinary Workshop, Toruń 19-21.10.2016

COGNITIVIST AUTUMN IN TORUŃ

Thank you for synchronization of your neurons!



Google: Wlodzislaw Duch
=> papers, talks, lectures …