SSCI Tutorial – December 8th, 2015

The Theory of neuronal Cognition

Claude TOUZET

Professor of Cognitive Science
Aix-Marseille University, F

claude.touzet@univ-amu.fr
http://claude.touzet.org/

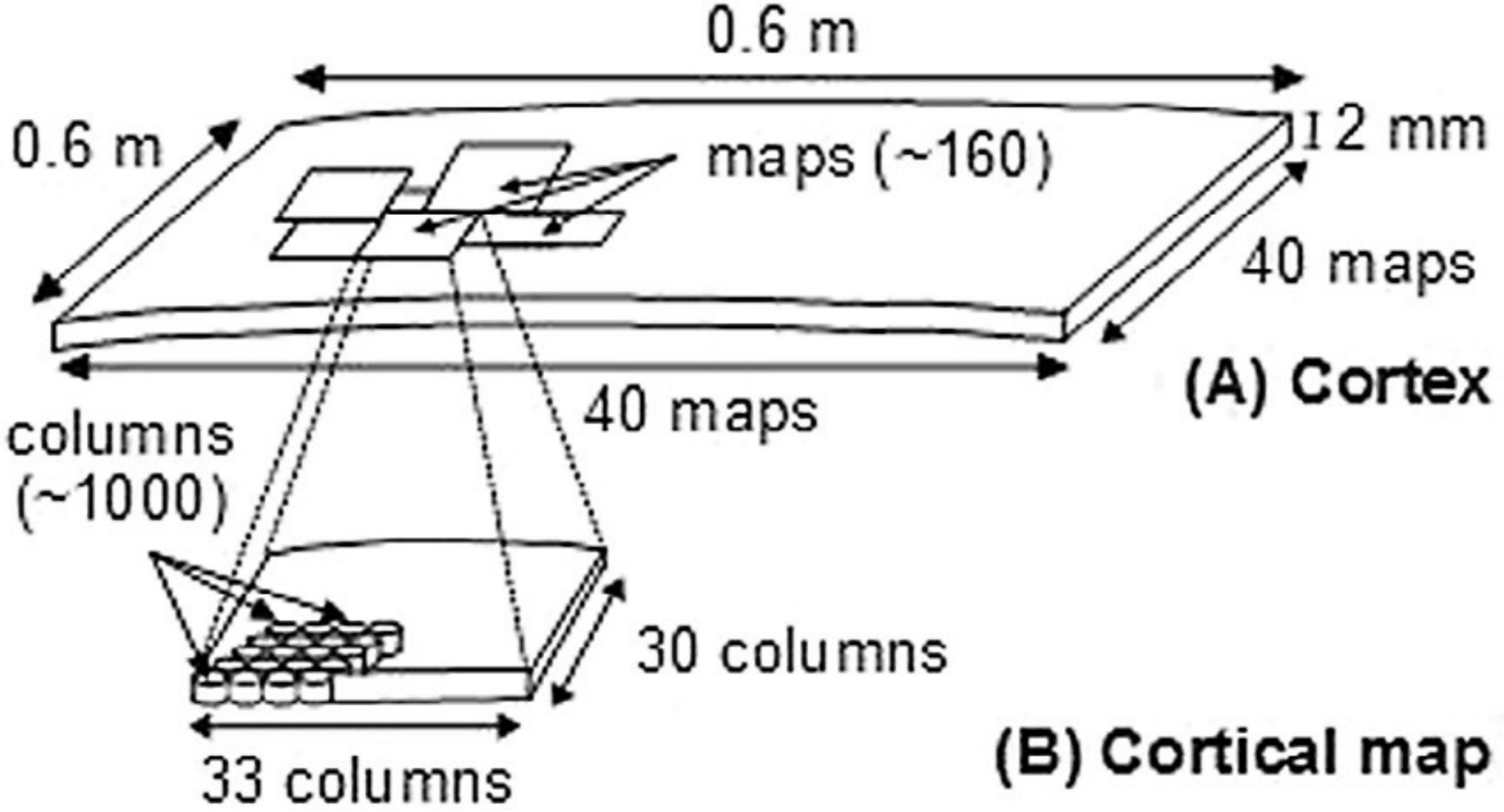
Aix*Marseille université

Abstract

The Theory of neuronal Cognition (TnC) was formalized in 2010 [6]. It explains how a hierarchy of self-organizing maps is able to display cognitive abilities including consciousness, intelligence, emotions, planning, reading [2], creativity, motivation, joy [5], etc. TnC explanation power encompasses modified states of consciousness (placebo effect, hypnosis, sleep [3]) as well as many mental diseases symptoms and therapies (such as for Alzheimer's disease, autism or schizophrenia). Of even more interest for the IEEE SSCI participants is the fact that the computing requirement of the TnC are limited [1] – because the processing unit is not the neuron [4], but the cortical column (and there are only 160,000 cortical columns in the human brain).

1. the cortical column as the elementary unit of cognition,
2. the cortical map as a self-organizing associative memory,
3. the cortex as a hierarchy of maps allowing multi-level abstraction,
4. the synergy between sensory and sensory-motor maps that generates behaviors,
5. the pregnant illusion of consciousness, better described as an automatic verbalization,
6. the relativity of intelligence, better describes as a side effect of the observer knowledge,
7. the implementations of endogenous and exogenous attentions, as also episodic and semantic memories,
8. motivation, or joy, as a side effect of associative memories functioning,
9. the unsupervised nature of homeostasis,
10. the ability to forecast and favor creativity.

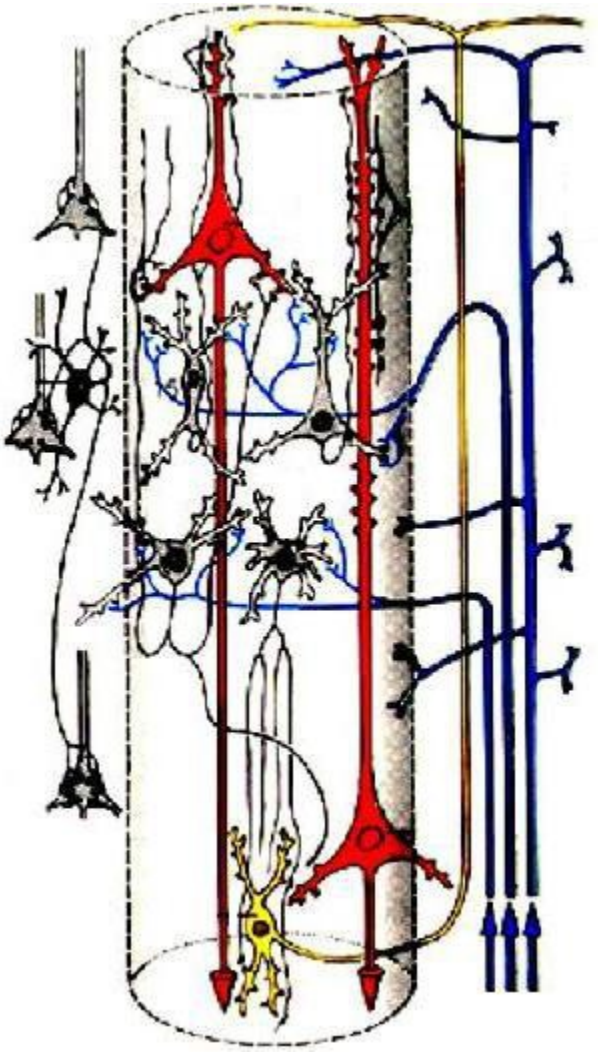
1. The cortical column as the elementary unit of cognition



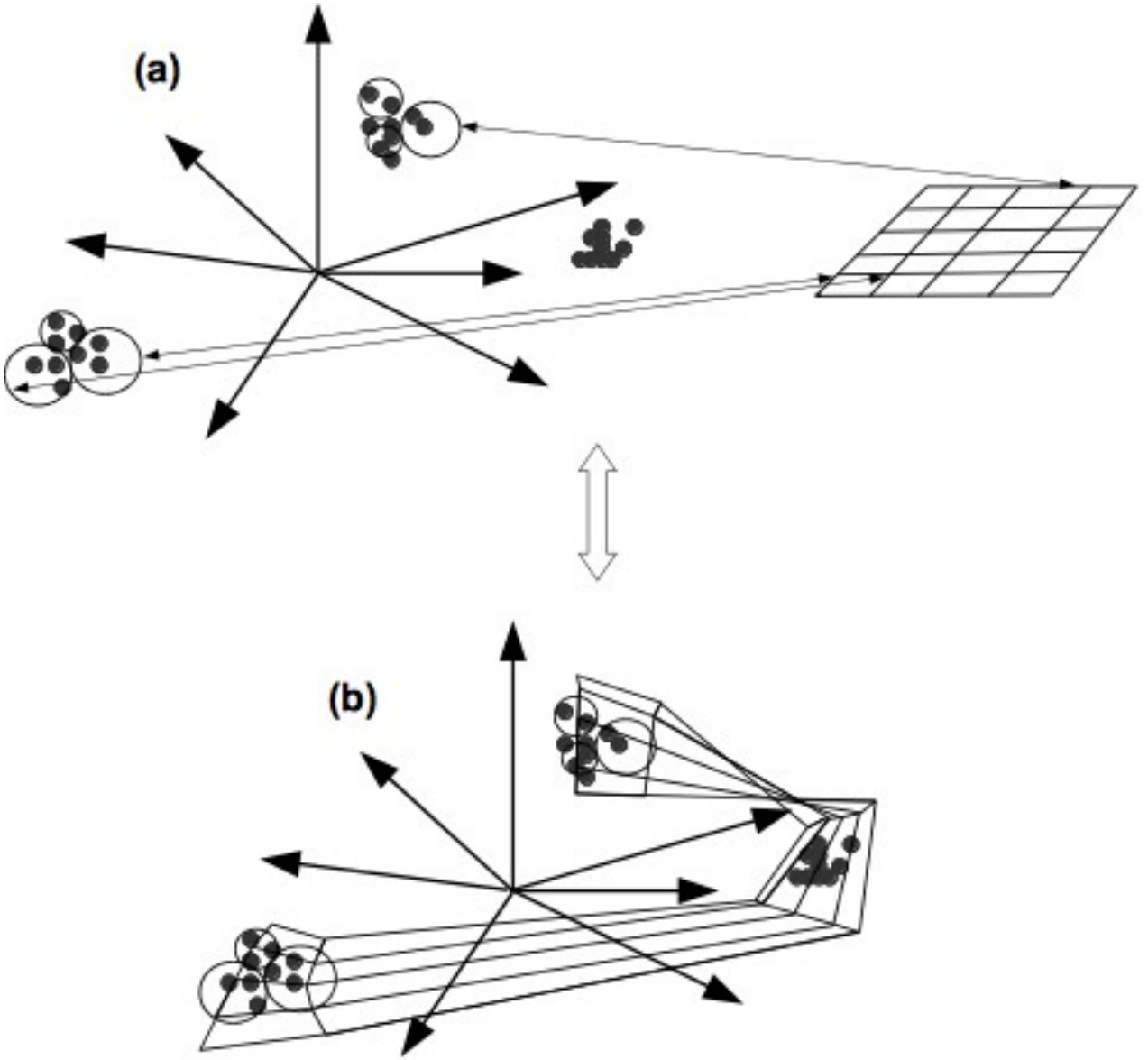
D. Hubel, *Eye, Brain, and Vision*, Freeman, May 1995. ISBN 978-0-7167-6009-2.
http://hubel.med.harvard.edu/book/ch5.pdf

1. The cortical column as the elementary unit of cognition

- Transmission of information (depolarisation) is very fast because the neuron « at rest » is already working (-60 mV).
- The cortical column activity does not exhibit the limitations of single neurons: activation can be sustained for very long periods (sec.) instead of been transient and subject to fatigue.
- 22% of the neurons belong to the cortex. The (human) cortex is composed of about 160,000 cortical columns (a column is a set of about 100,000 neurons), each column belonging to one of the estimated 160 cortical maps (80 are labelized)

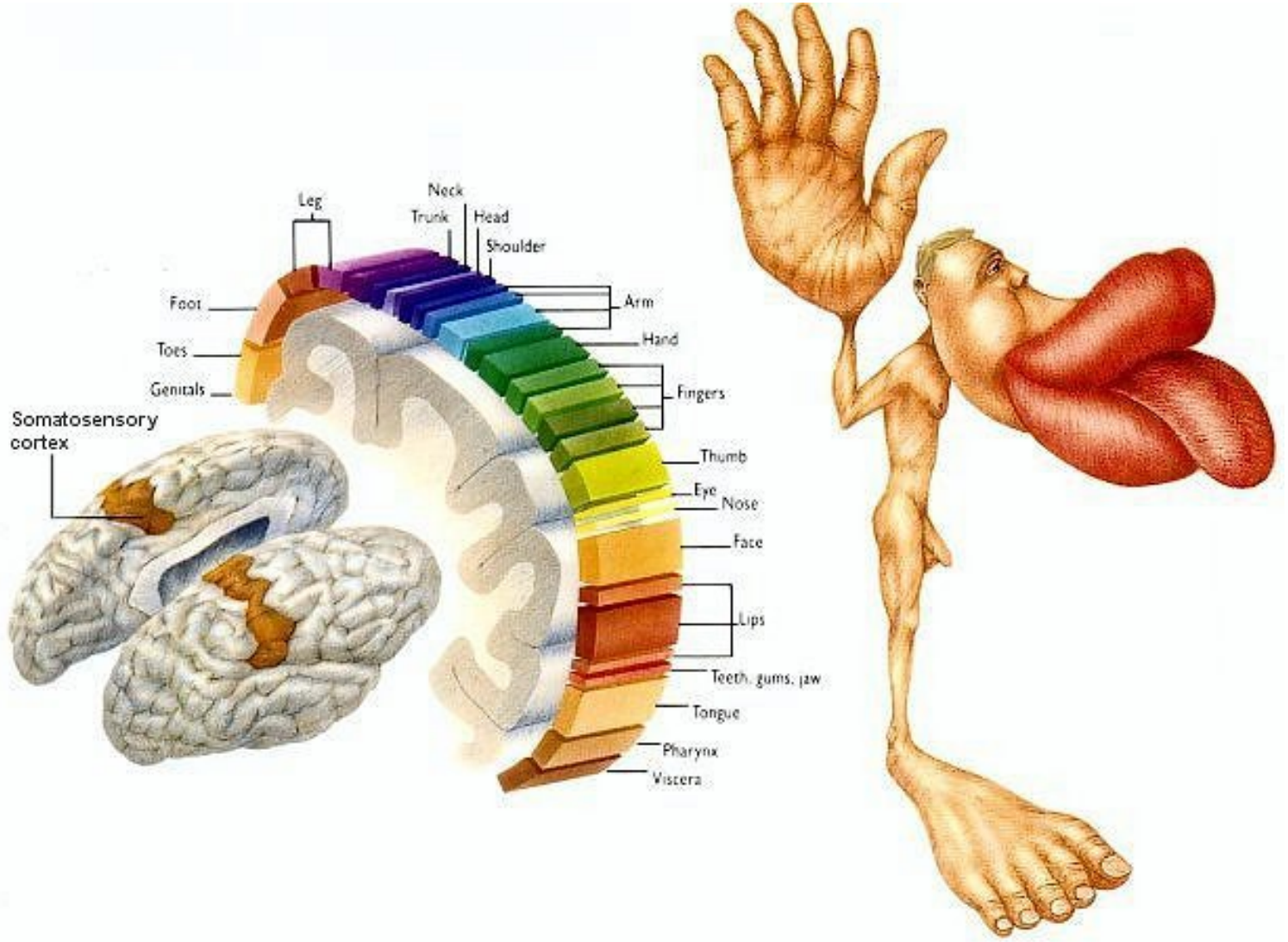


2. The cortical map as a self-organizing associative memory



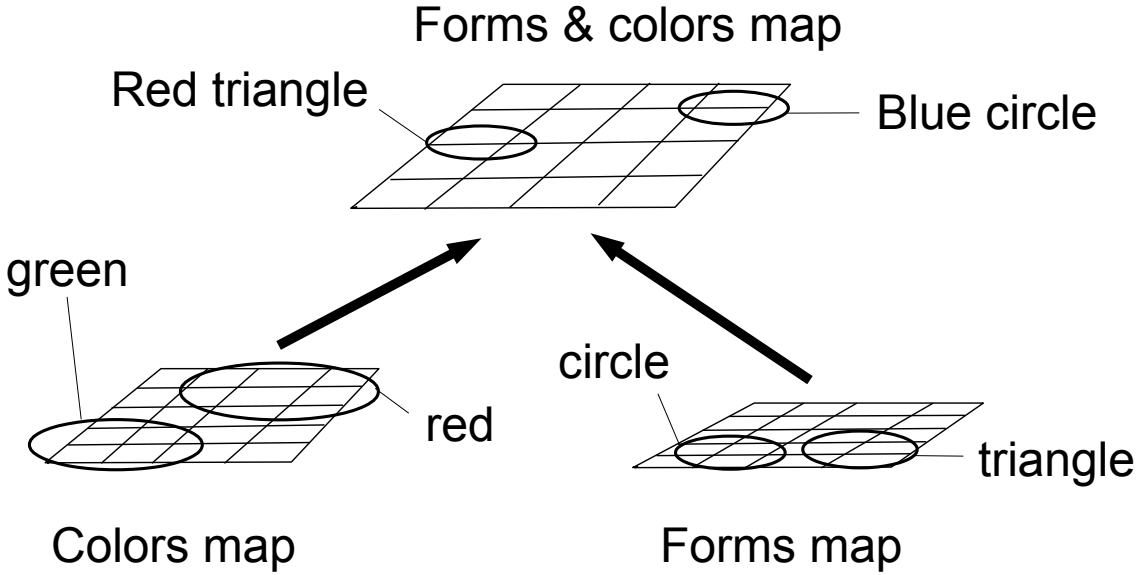
Teuvo Kohonen, *Self-Organizing Maps, Springer Series in Information Sciences, Vol. 30*, 2001. Third Ed., 501 pages. ISBN 3-540-67921-9, ISSN 0720-678X

2. The cortical map as a self-organizing associative memory



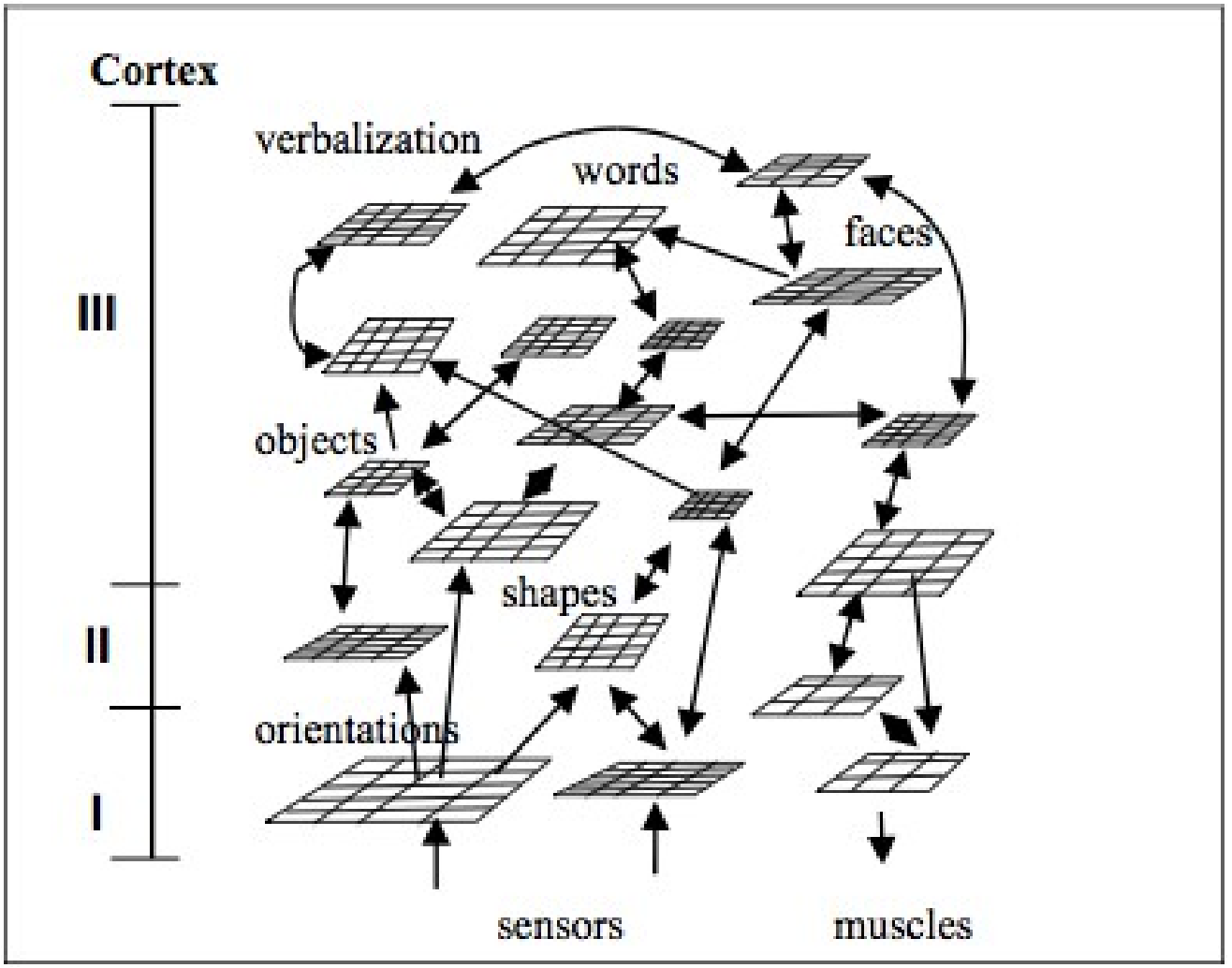
W. Penfield, T. Rasmussen, *The cerebral cortex of man*, Macmillan, 1950.

3. The cortex as a hierarchy of maps allowing multi-level abstraction



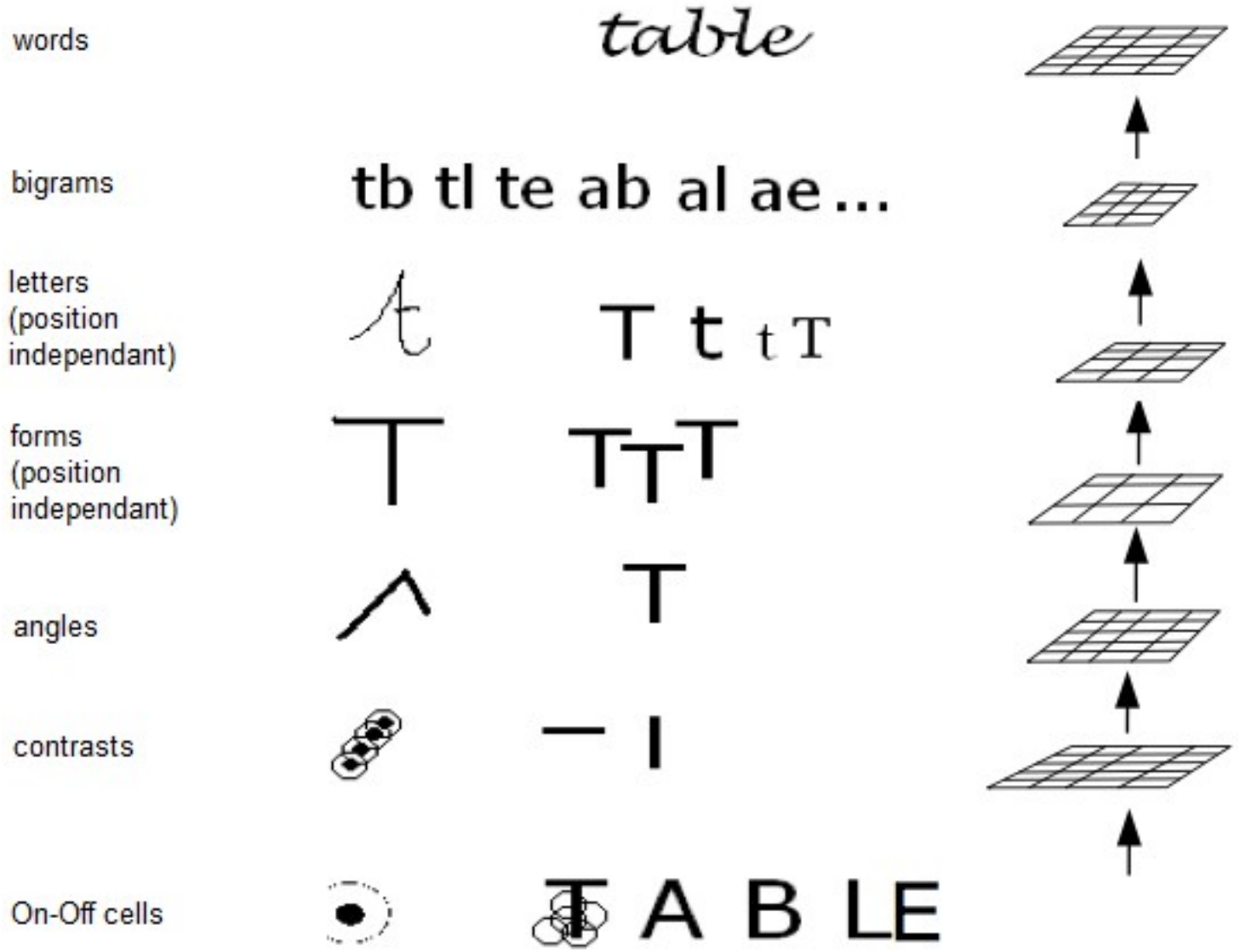
- The illusion of semantics

3. The cortex as a hierarchy of maps allowing multi-level abstraction



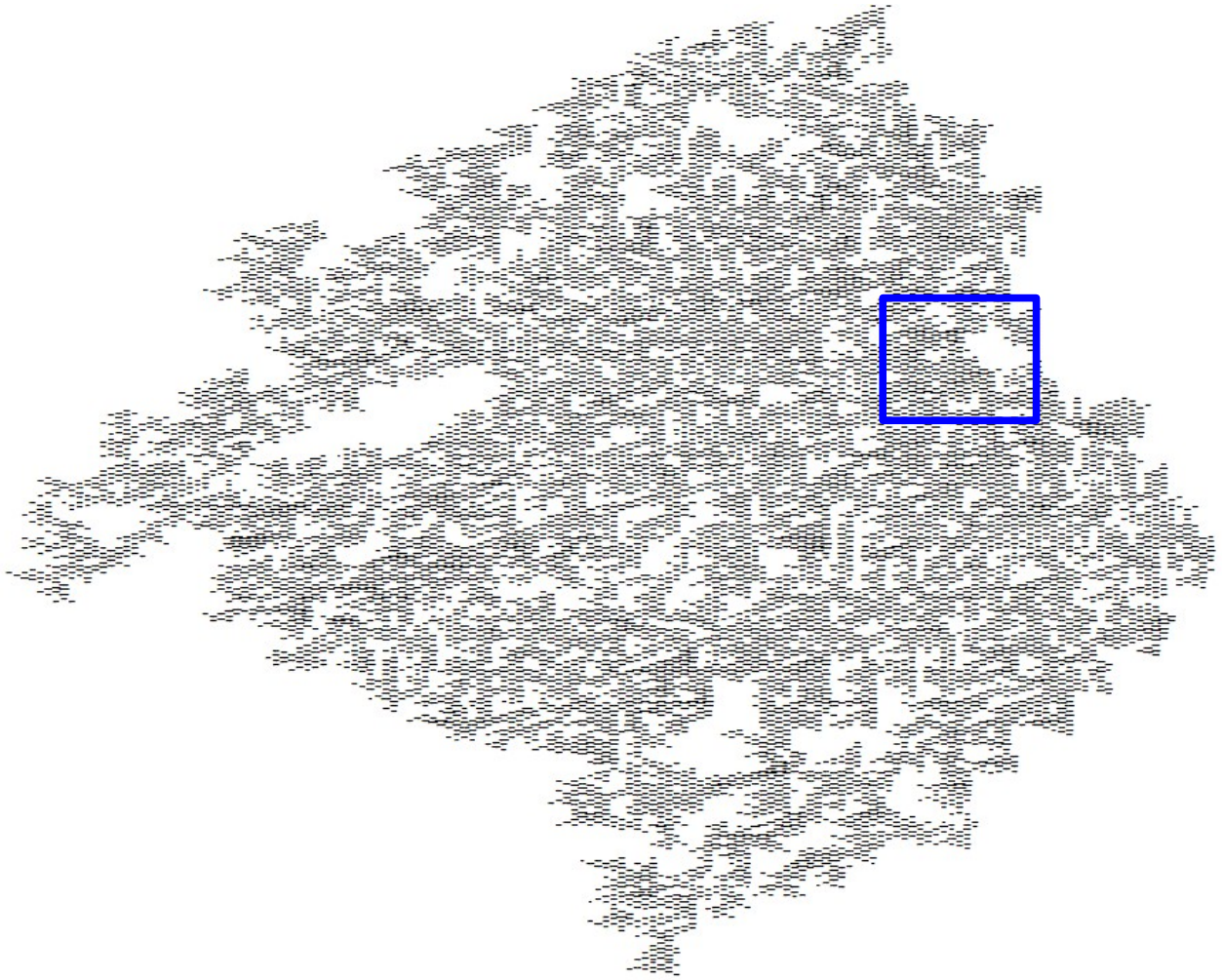
M. Silver and S. Kastner (2009) – Topographic maps in human frontal and parietal cortex, *Trends in Cognitive Sciences*, Vol. 13, No. 11, 488-495.

3. The cortex as a hierarchy of maps allowing multi-level abstraction



Dehaene, S., Cohen, L., Sigman, M., & Vinckier, F. (2005). The neural code for written words: a proposal. *Trends Cogn Sci*, 9(7), 335-341.

3. The cortex as a hierarchy of maps allowing multi-level abstraction



C. Touzet, A Biologically Plausible SOM Representation of the Orthographic Form of 50,000 French Words, *WSOM 2014* (10th Workshop on Self-Organizing Maps), July 2014, Mittweida, G.

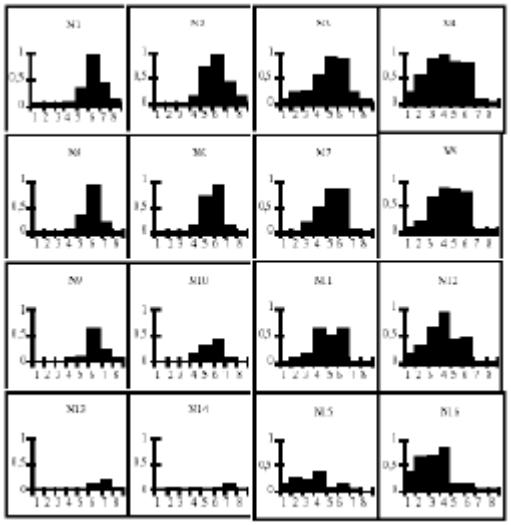
3. The cortex as a hierarchy of maps allowing multi-level abstraction

4. The synergy between sensory and sensory-motor maps that generates behaviors

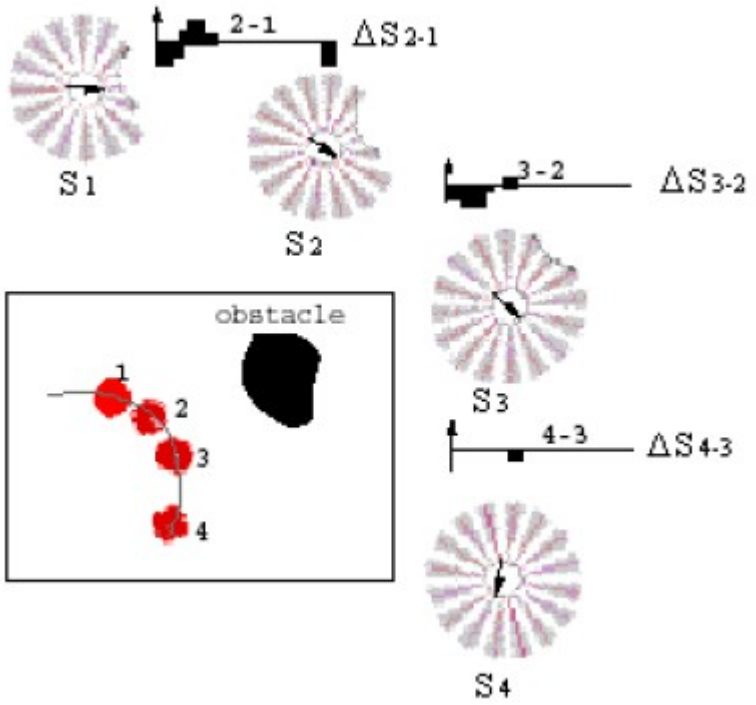
Khepera (8 IR)

Nomad (16 sonar)

4. The synergy between sensory and sensory-motor maps that generates behaviors



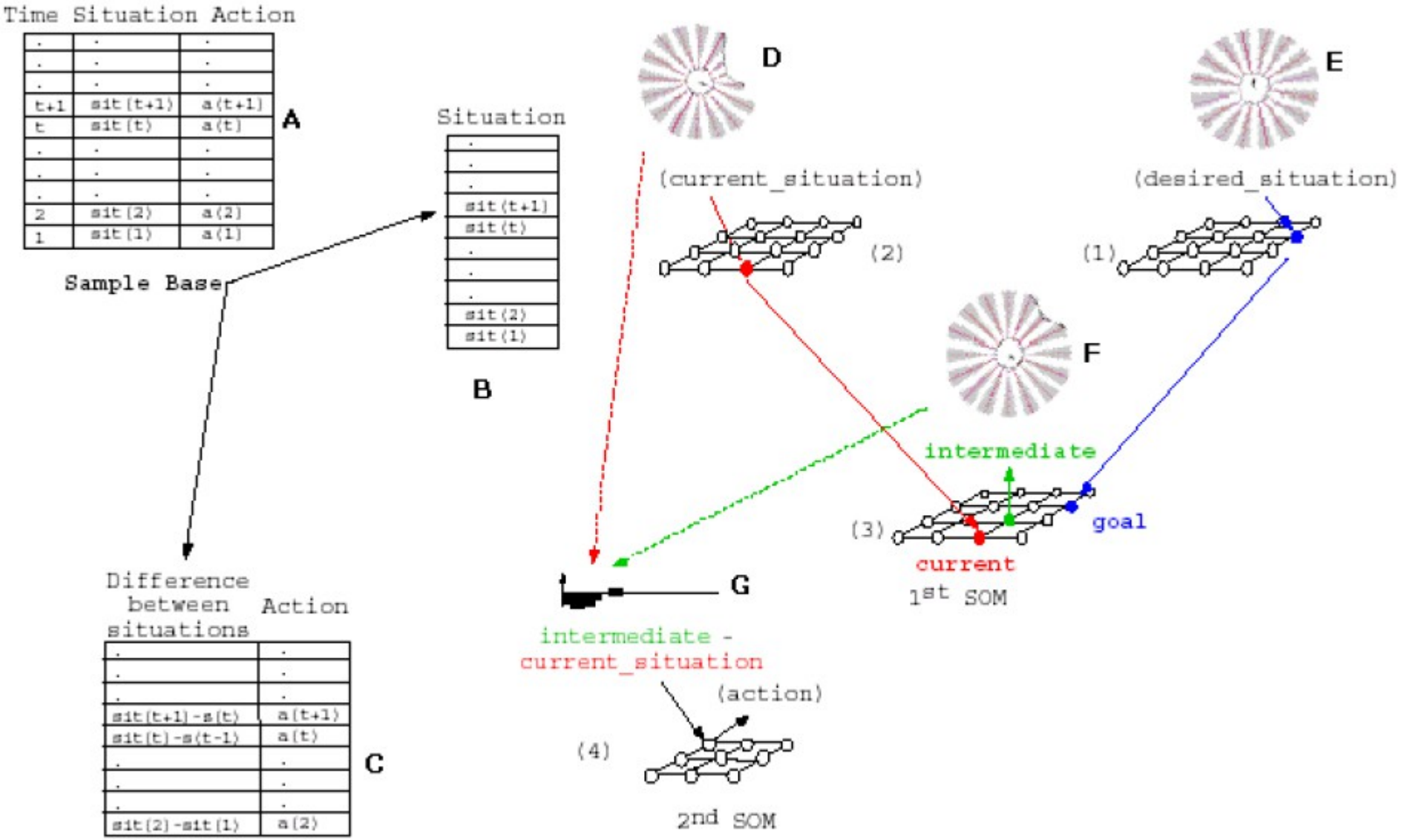
100 learning iterations
(16 neurons SOM)



Variations of situations

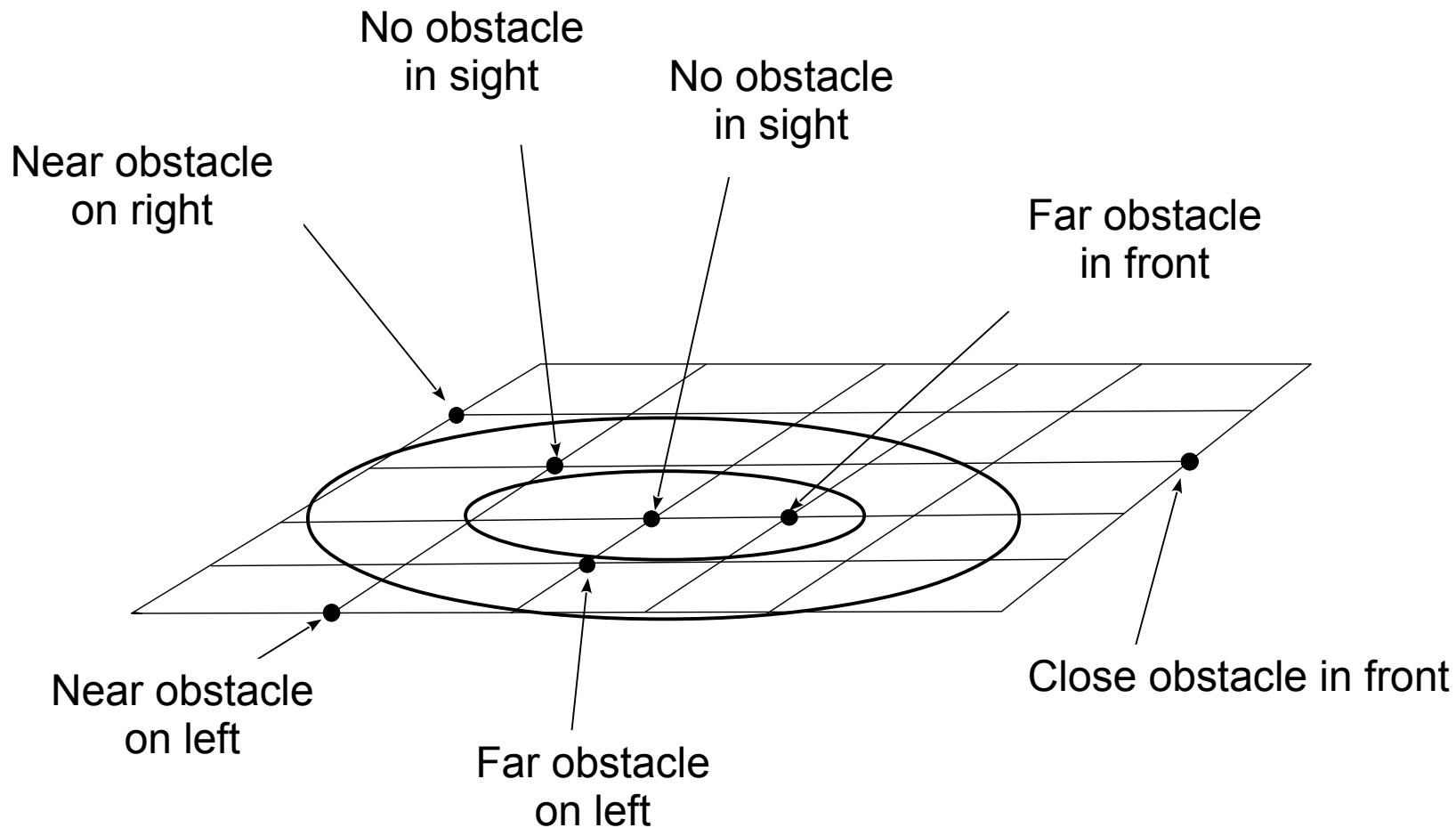
C. Touzet, "Modeling and Simulation of Elementary Robot Behaviors using Associative Memories", *International Journal of Advanced Robotic Systems*, Vol 3 n° 2, June 2006.

4. The synergy between sensory and sensory-motor maps that generates behaviors



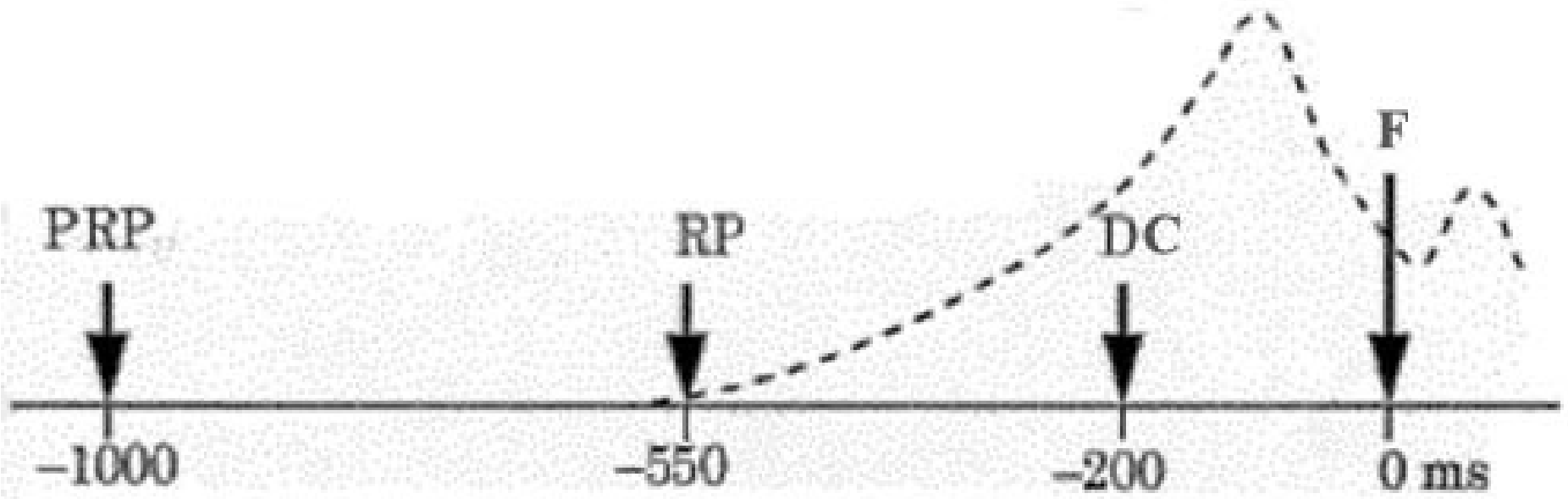
Synthesizing a sequence of actions respectively to a goal

4. The synergy between sensory and sensory-motor maps that generates behaviors



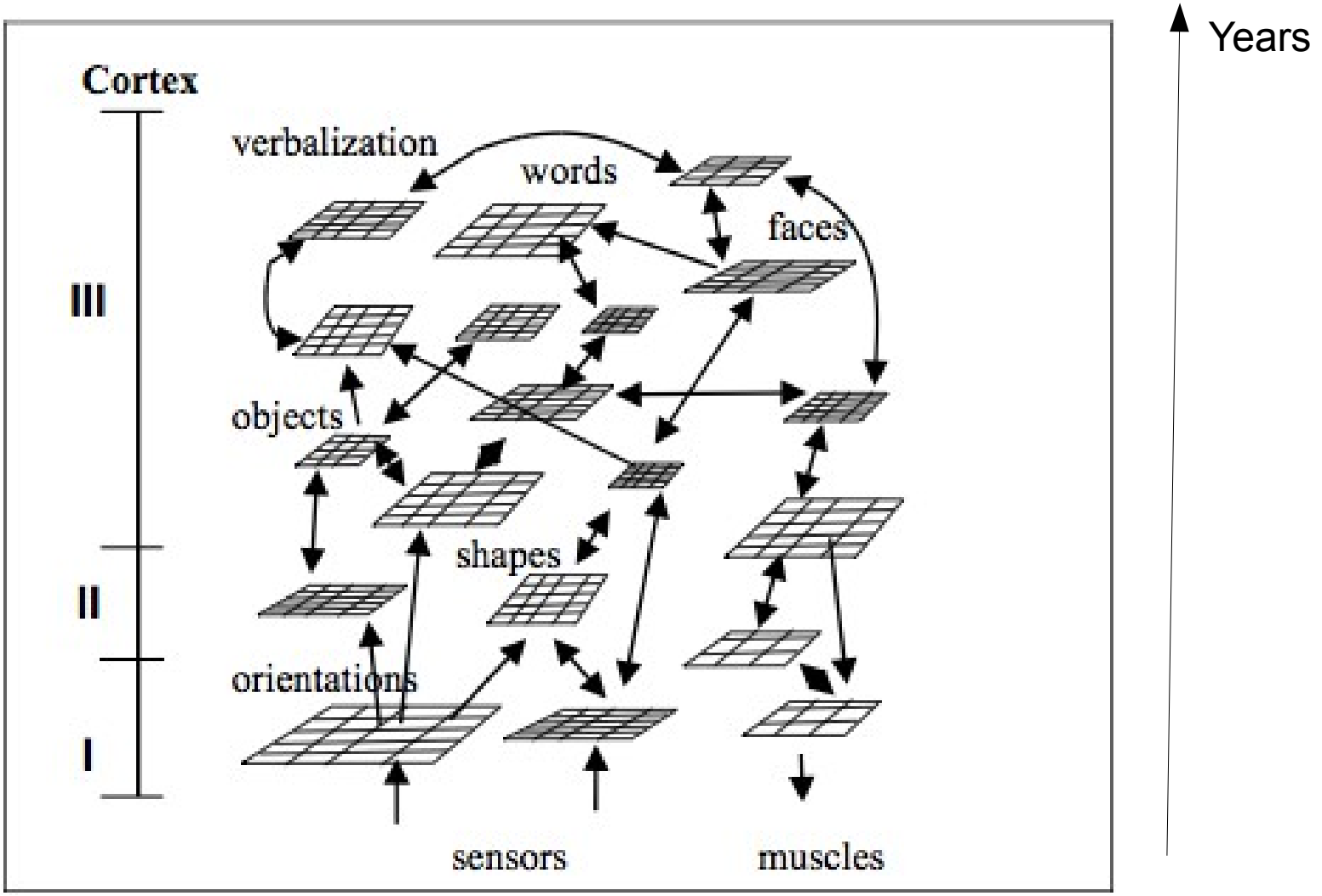
Immediate synthesis of multiple behaviors: hunting, avoiding, following, ...

5. The pregnant illusion of consciousness, better described as an automatic verbalization



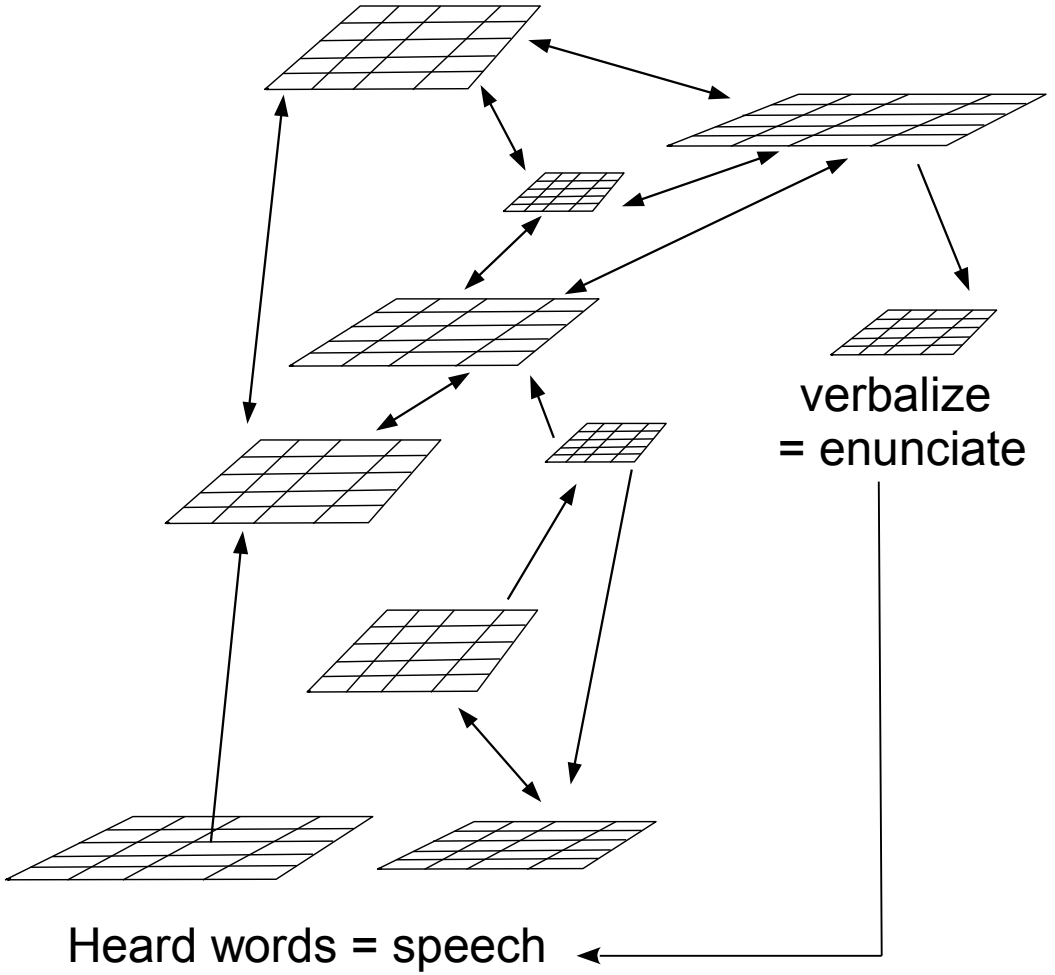
Libet, Benjamin (1985). "Unconscious Cerebral Initiative and the Role of Conscious Will in Voluntary Action". *The Behavioral and Brain Sciences* 8: 529–566.

5. The pregnant illusion of consciousness, better described as an automatic verbalization



- Feral childs, critical periods of development

5. The pregnant illusion of consciousness, better described as an automatic verbalization



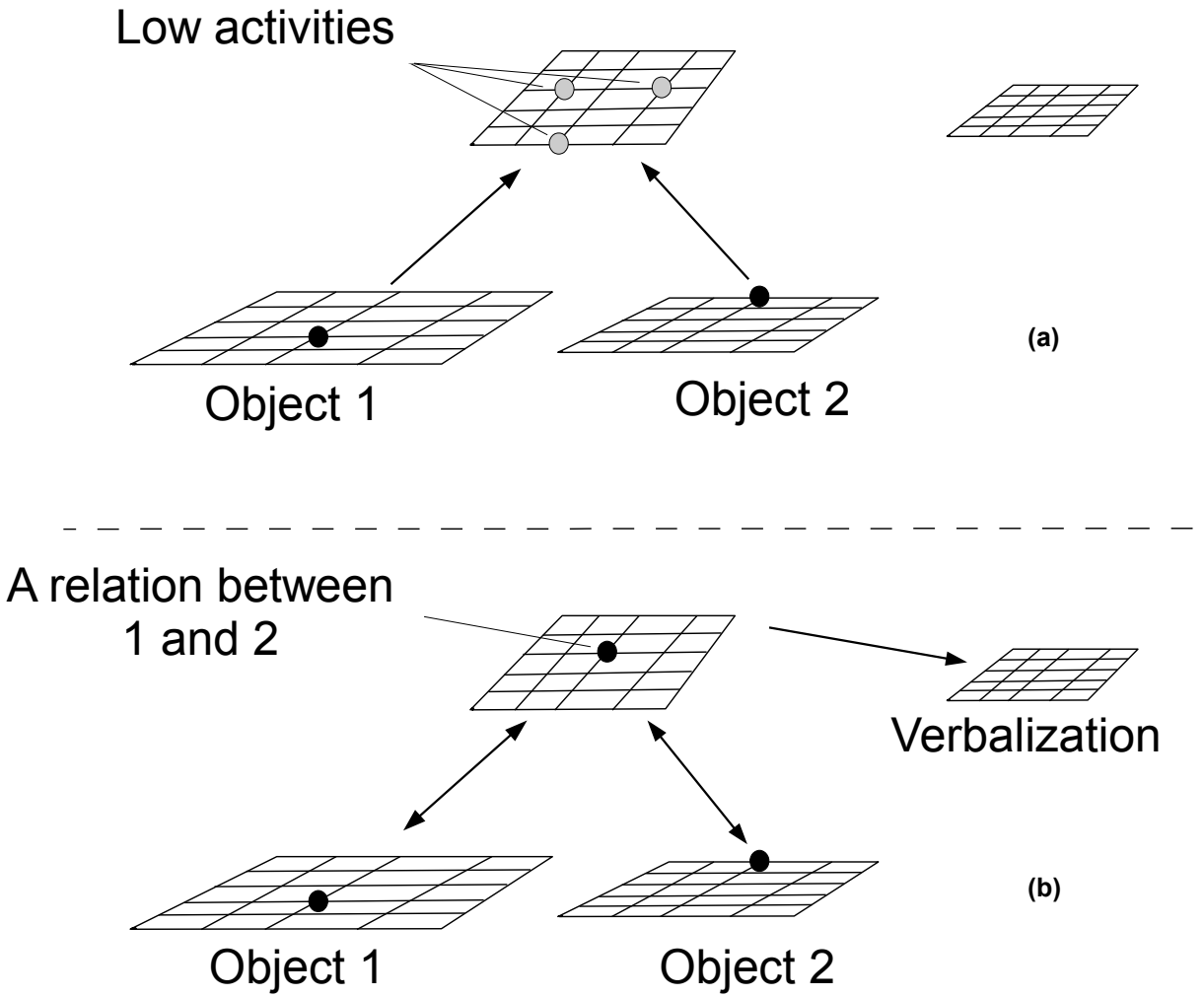
- Baby-sitting

- internal voice
- speech

6. The relativity of intelligence, better describes as a side effect of the observer knowledge

- Something is (or isn't) « intelligent » depending on the knowledge of the observer.
- Since intelligence is relative, scales such as the IQ do not test or measure « intelligence » but knowledge. Have you already be in such situation (or a similar one) ?
- Comparing the IQ scores of young and senior people is meaningless.

6. The relativity of intelligence, better describes as a side effect of the observer knowledge



a matching of two (until yet unrelated) objects

7. The implementations of endogenous and exogenous attentions, as also episodic and semantic memories

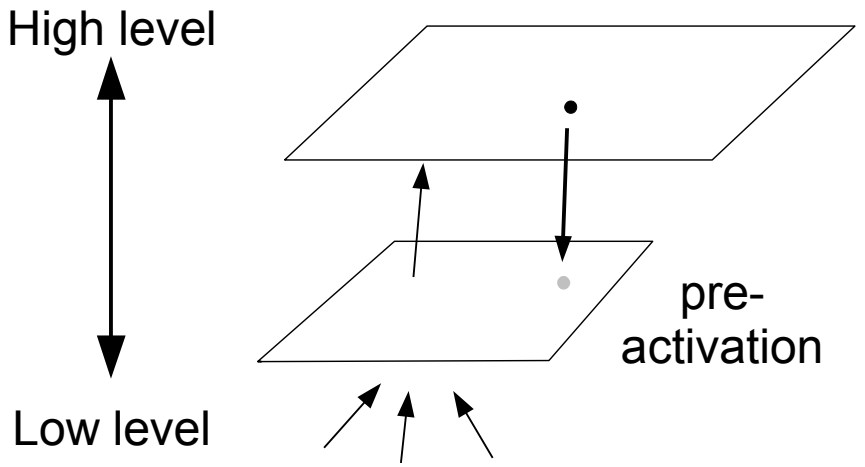
Hebb learning rule:

"Let us assume that the persistence or repetition of a reverberatory activity (or "trace") tends to induce lasting cellular changes that add to its stability.… When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased."

- And vice versa...
- A or B alone ?
- Inhibitory neurons ?
- Only known learning rule
- Pure local learning

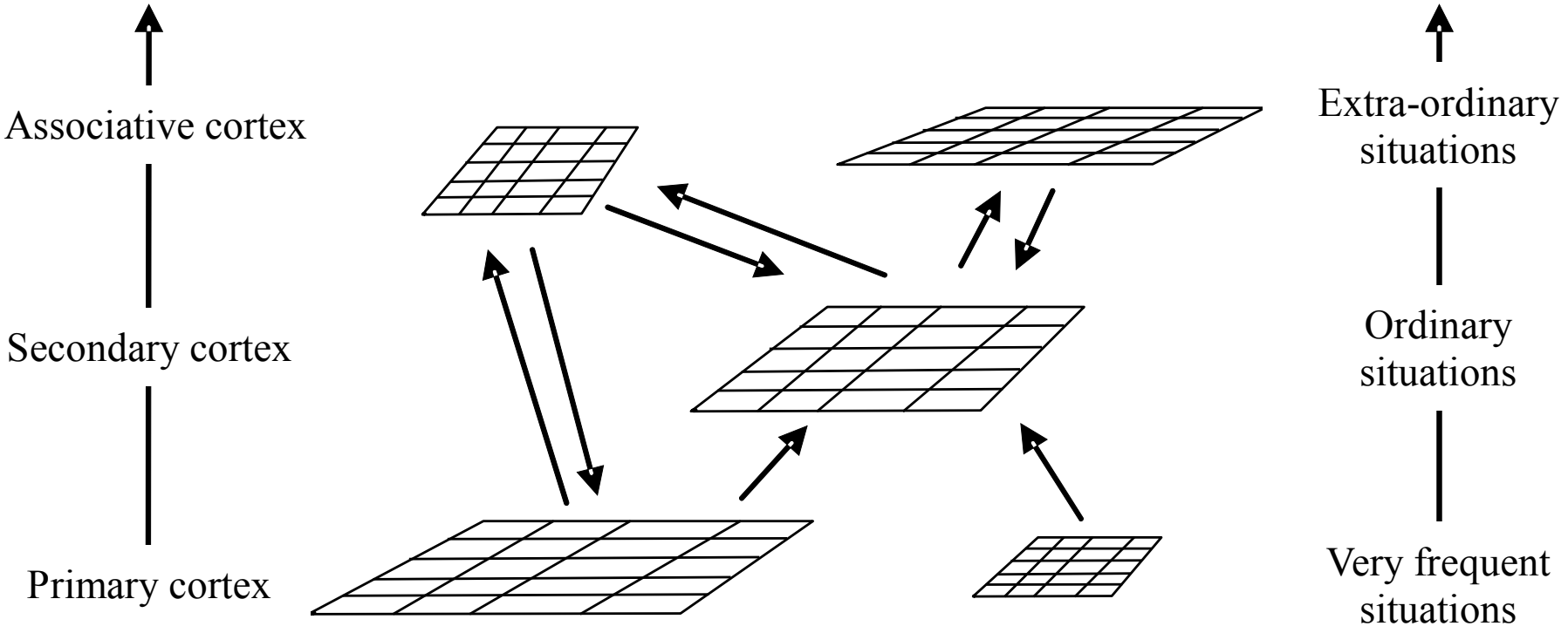
Donald Hebb, *The Organization of Behavior : A Neuropsychological Theory,* Wiley, 1949.

7. The implementations of endogenous and exogenous attentions, as also episodic and semantic memories



Endogenous attention - top-down

7. The implementations of endogenous and exogenous attentions, as also episodic and semantic memories



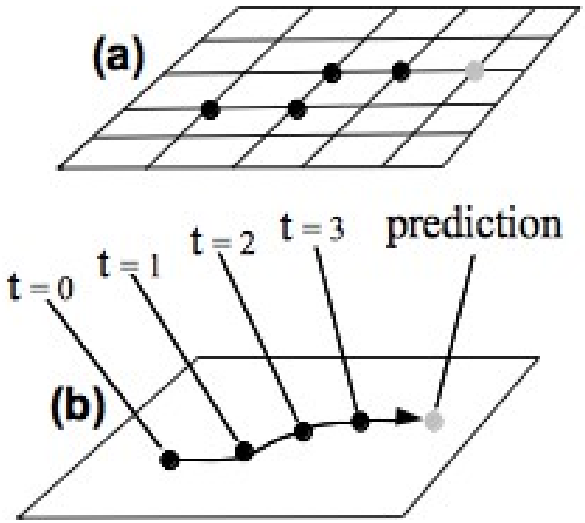
l	1	2	3	4	10	12
%	100	20	4	0.8	$5\ 10^{-5}$	$4\ 10^{-7}$

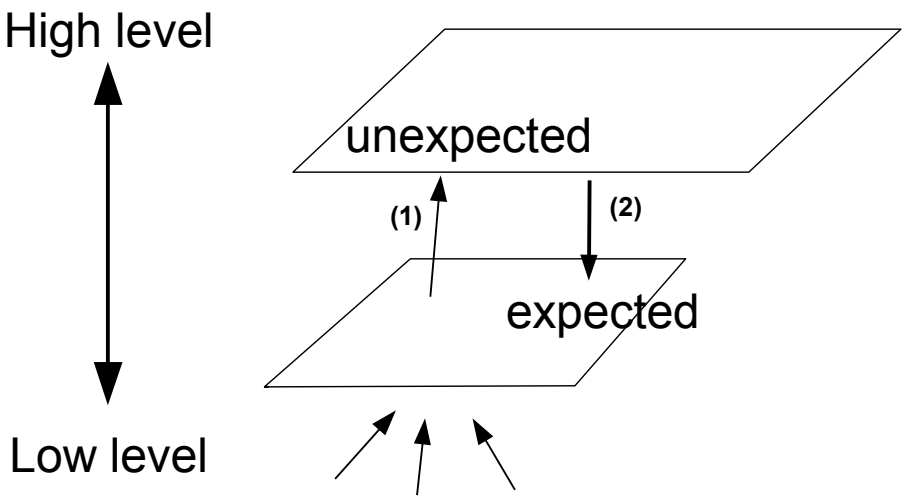
SOM as a regularity detector

7. The implementations of endogenous and exogenous attentions, as also episodic and semantic memories

« Selecting one aspect of the environment while ignoring other things »

- Prediction
- A-causal backward connections – loops (novelty filter)

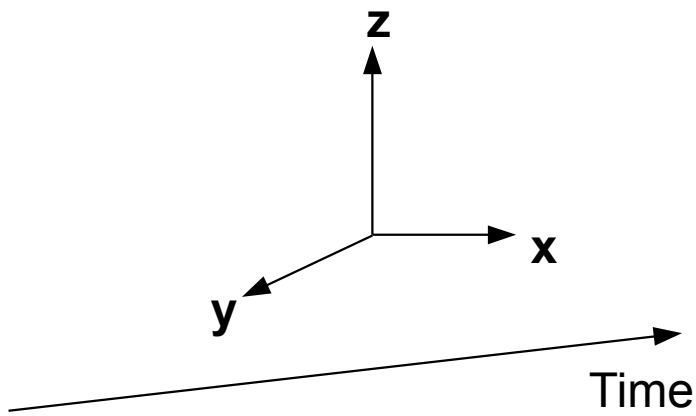




Exogenous attention - bottom-up

7. The implementations of endogenous and exogenous attentions, as also episodic and semantic memories

- Episodic memories: time and space coordinates
- Semantic memories : no coordinates

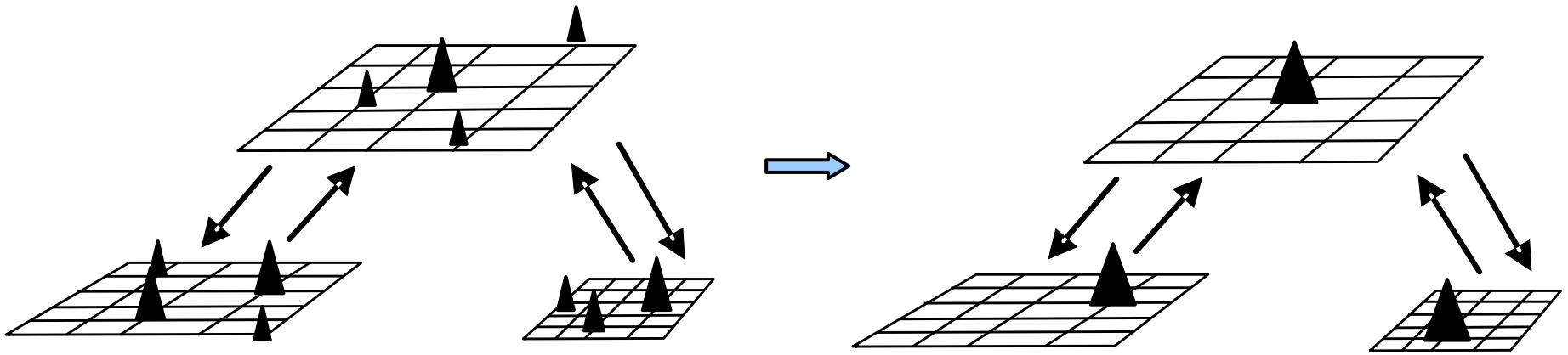


Charles R. Gallistel, *The Organization of Learning, MIT Press, 1993.*

8. Motivation, or joy, as a side effect of associative memories functioning

Def.: A behaviour without an explicit (enough) goal

- The smallest common activation pattern between multiple memorized events is an attractor state.



(a) (b)

Touzet C (2011) « The Illusion of Joy » In : J. Schmidhuber, K.R. Thórisson, and M. Looks (Eds.) *Artificial General Intelligence 2011*, Springer LNAI 6830, pp. 357-362.

9. The unsupervised nature of homeostasis

Evolution of the learning algorithms toward less and less supervision:

- Supervised learning (Perceptron, 1959)
- Self-organisation (data base, 1977)
- Supervised learning (learning base, 1985)
- Reinforcement learning (evaluation function, 1994)
- Associative memory programming (targets, 2006)
- Palimpsest learning (2014)

9. The unsupervised nature of homeostasis

Hebb+:

It takes time to strengthen the synapse. If during this duration, there is a new activation of one or both of the neurons, the current modification will stop short to be replaced by the new one. Therefore, only a modification - no followed too quickly by another one - is going to be complete.

Since an equilibrium is defined by the fact that the frequency of changes is particularly low, then the last “action” of the neurons will be well recorded, and easily replayed next time the situation is similar. Palimpsest learning favors the emergence of equilibriums or “homeostasis”.

9. The unsupervised nature of homeostasis

Palimpsest learning explains:

- How well-timed additional information (supervision) help organize the various cortical maps,
- Why you must climb again on your horse after fall,
- Why a child must repeat until his/her pronunciation is correct.

10. The ability to forecast and favor creativity

Def.: *the proposal of something new and valuable.*

Forecast:

- Self-organization through experience of the high-level cortical maps, and improvement by repetitions.
- Continuity of the representation of the events on –at least– one cortical map.
- SOM trajectories allow predictions.

Favor:

- Thinking outside the box: multidisciplinarity, regular changes of topics.

References

- Touzet C (2015) "The Theory of Neural Cognition applied to Robotics", *Int J Adv Robot Syst* **12**:74 | doi: 10.5772/60693.
- Touzet C, Kermorvant C, Glotin H (2014) "A Biologically Plausible SOM Representation of the Orthographic Form of 50,000 French Words", in: Villmann, Th., Schleif, F.-M., Kaden, M., Lange, M. (Eds.) *Advances in Self-Organizing Maps and Learning Vector Quantization*, Springer AISC **295**:303-312.
- Touzet C (2014) *Hypnosis, Sleep, Placebo: the answers from the Theory of neuronal Cognition – Tome 2*, Ed. la Machotte, 166 pages. (in French) ISBN: 978-2-919411-02-3.
- Touzet C (2013) "Why Neurons are Not the Right Level of Abstraction for Implementing Cognition", in A. Chella, R. Pirrone, K. Jóhannsdóttir, R. Sorbello (Eds.) *Biologically Inspired Cognitive Architectures 2012*, AISC**196**:317-318.
- Touzet C (2011) "The Illusion of Joy", in J. Schmidhuber, K.R. Thórisson, and M. Looks (Eds.) *Artificial General Intelligence 2011*, Springer-Verlag LNAI **6830**:357–362.
- Touzet C (2010) *Consciousness, Intelligence, Free-will: the answers from the Theory of neuronal Cognition*, Ed. la Machotte, 156 pages. (in French) ISBN: 978-2-919411-00-9