Bayesian Modeling of Cerebral Information Processing

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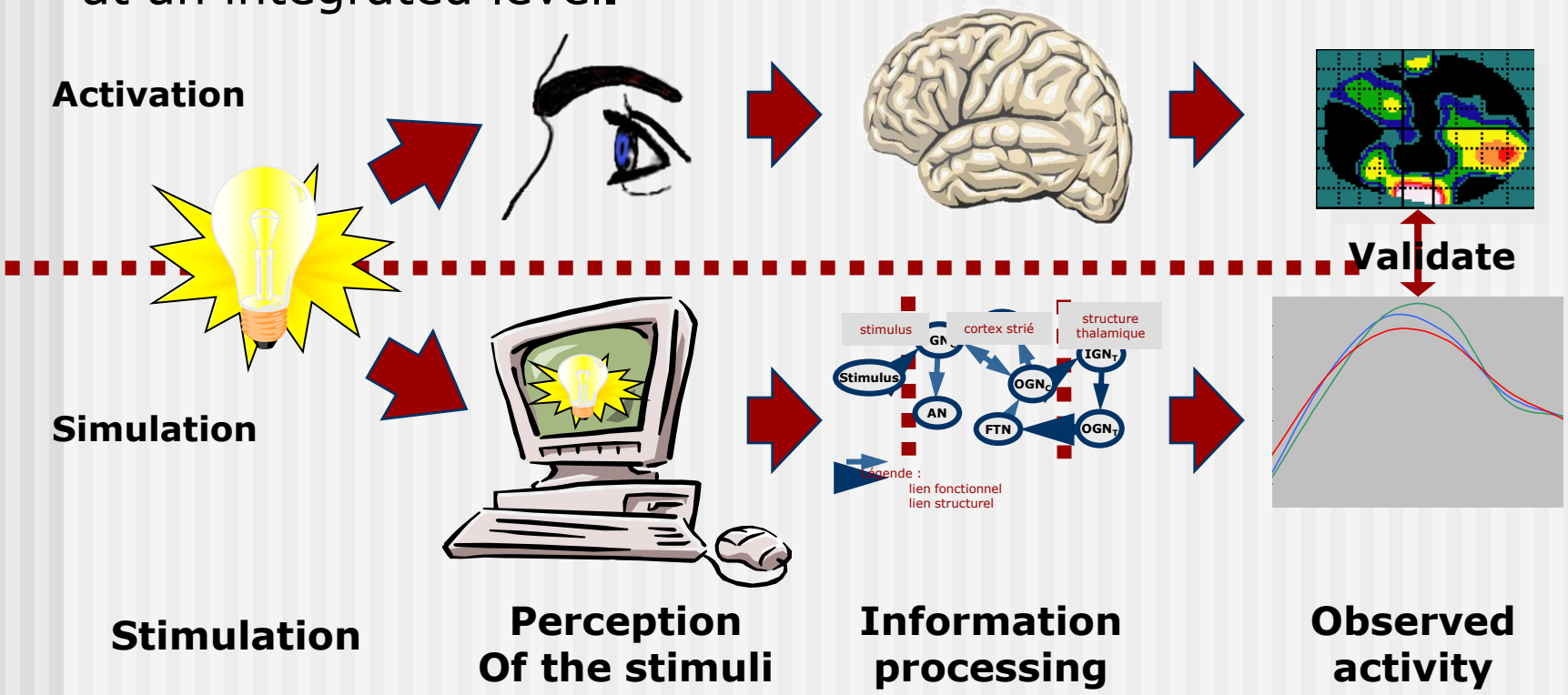
MITIC presentation

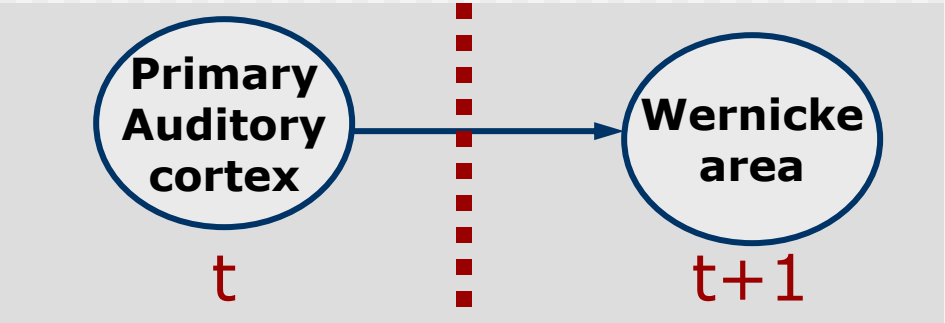
- **Objective** of the **M.I.T.I.C.** project (Integrated Modeling of Cerebral Information Processing): to determine the links between the brain's **physical structure** and its **functioning**, at an integrated level**.**



MITIC specifications

A CAUSAL MODEL

- **Biological** justification (the transmission of the **cerebral signal** is **causal**).



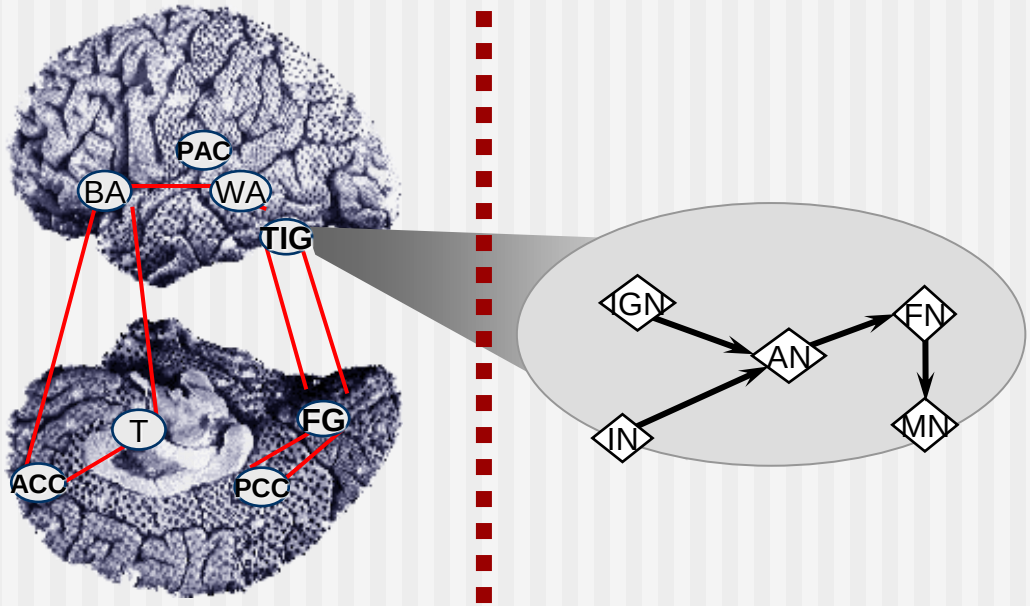
- Spatial and temporal **adjacency**.
- Statistical **regularity**.
- Temporal **consistency**.

- **Experimental/medical** justification (the **hypotheses** are expressed in terms of causes and effects).

MITIC specifications

A FUNCTIONAL AND STRUCTURAL MODEL

We need **both** representation levels in order to link the brain's **structure** and its **functioning**.



Large-scale network of cerebral regions implements high-level cognitive functions.

Constraints on the formalism

- The brain is a **dynamical** system.
- **Causality**

- Cerebral relationships may
- **Habituation** mechanisms.
- **Long term** learning.

imaging data.

- The brain can react differently (**uncertainty**) to the same stimuli.

Temporality

Conditioning

Non-linearity

Learning

Categorization

Uncertainty and/or **imprecision**

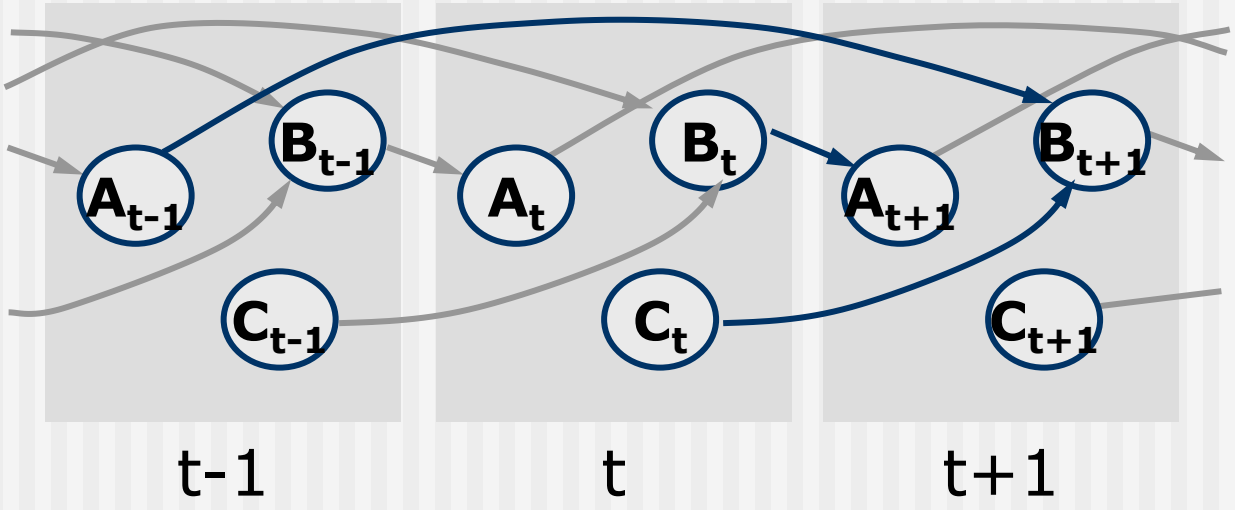
Causal functional networks [Pearl, 99]

- a set of random variables (nodes).
- a set of deterministic functions (edges).

If ***A*** and ***C*** are ***B***'s causes, then:

$$B := f_B(A, C, u_B)$$

Where u_B is a random variable standing for the error, and f_B can be a non-linear function.



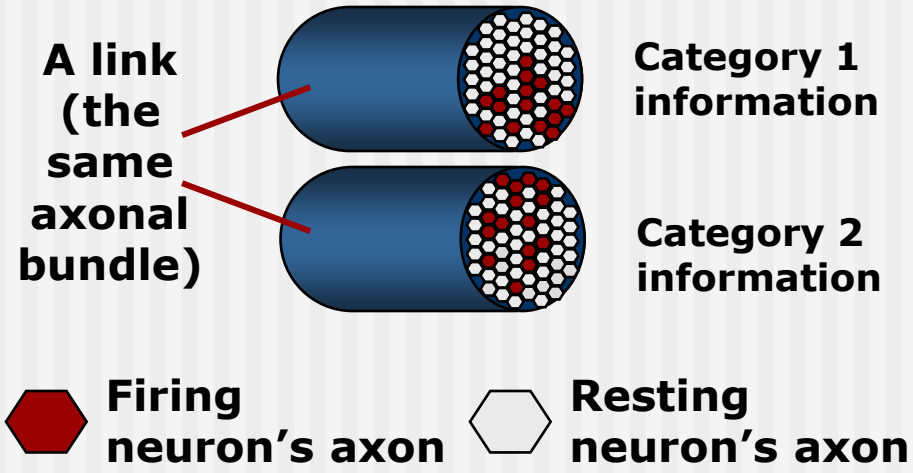
Causal functional networks [Pearl, 99]

Causal relationships	→	**Causality**
Explicit representation of **time**	→	**Temporality**
Conditions with deterministic functions	→	**Conditioning**
Non-linear relationships	→	**Non-linearity**
Learning mechanisms	→	**Learning**
Manipulation of **symbolic** values	→	**Categorization**
Measure of **uncertainty**	→	**Uncertainty** and/or **imprecision**

Information representation

In order to agree with the **categorization** constraint, the propagated and computed information is a couple (**Magnitude**, **Category**).

- **category**: identity of the concerned **neuronal population** (**what ?**).
- **magnitude**: intensity of the response (**How much ?**).



Two different categories of information, the same magnitude.

Measure of the imprecision

Two applicable solutions:

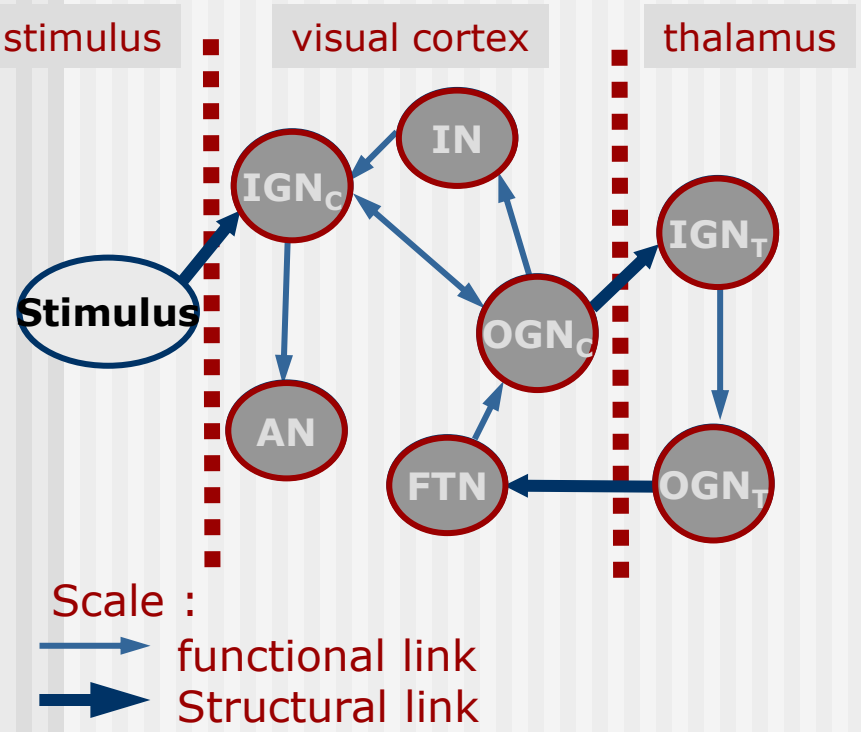
- to use a mean value and a dispersion measure to represent magnitude: $X_M = (m_x, \sigma_x)$.
- or to use the possibilistic theory instead of the probabilistic one.

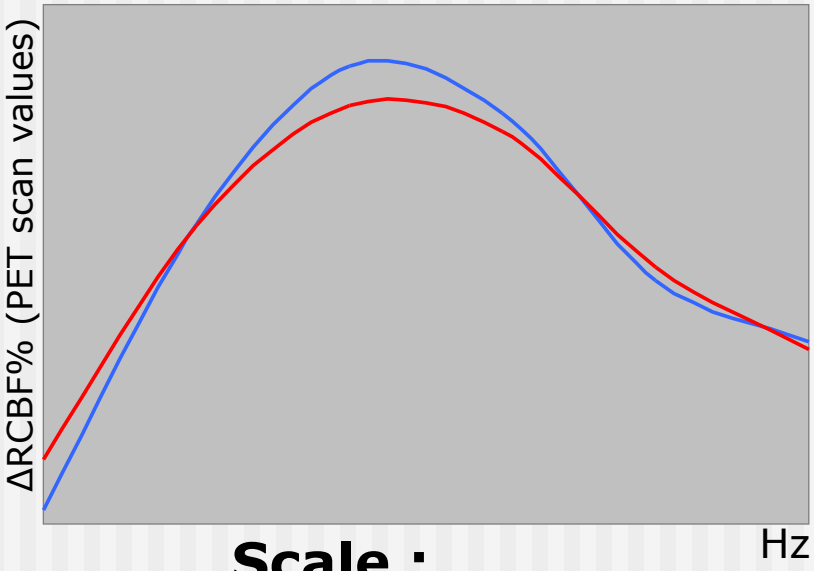
Advantages of the probabilities:

- more mathematical tools.
- statistical processing of neuroimaging data.

An example of application

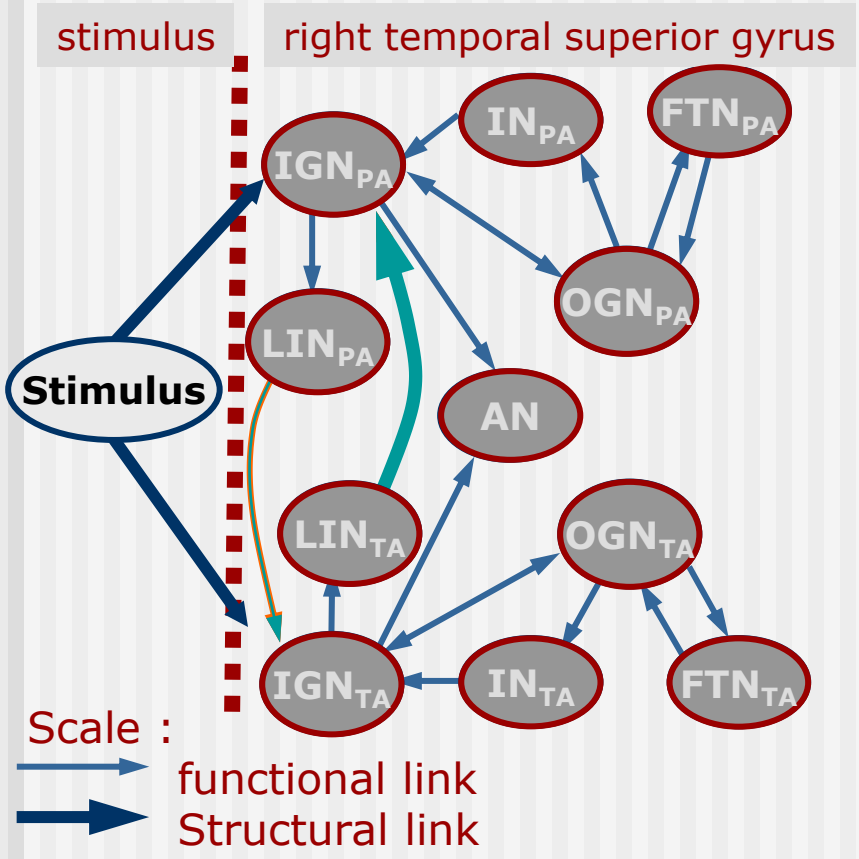
The formalism has been used to approach results obtained experimentally (PET) by Fox & Raichle [1984].

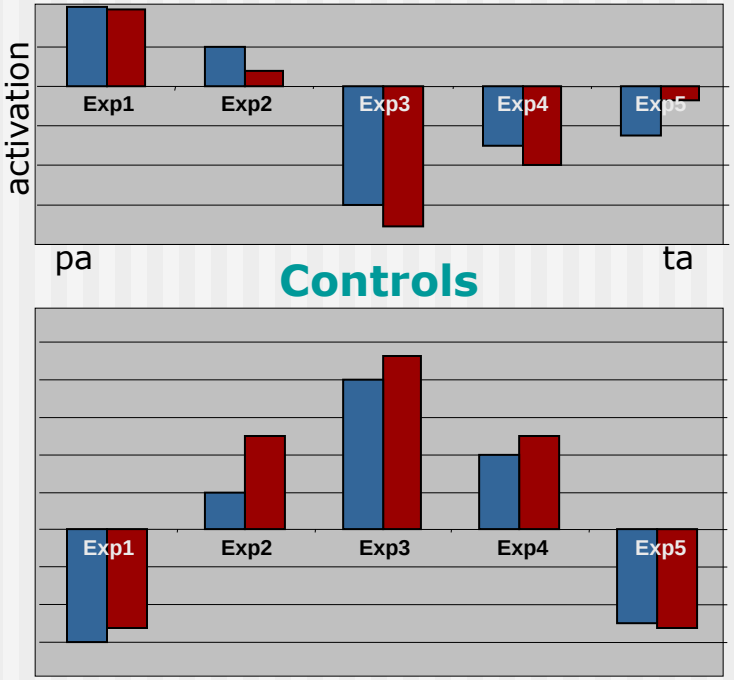




An example of application

Another model, based on Ruff's experiment (fMRI) [Ruff, 2000].





Discussion & perspectives

- **Applicability** of our formalism.
- **Possible interventions** in the model (previous example).
- **Processing of the conditions**: two possible choices : to process all the cases (NP-hard) or only the most probable ones (loss of information).
- Using normal random variables: difficulties to combine **non-linearly** this type of variables (the normality property is lost).