

# DYNAMIC BAYESIAN NETWORKS FOR INTEGRATED NEURAL COMPUTATION

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## CONTEXT

- Analysis of neuroimaging activation data give a sketch of the large-scale networks implementing cognitive or sensorimotor functions.
- However, there is no one-to-one correspondence between lesions and cognitive dysfunctions.

## GOALS

- Answer how the **activation** derives from the integrated neural computation in large-scale cerebral networks.
- Provide a **modeling** tool explicit enough to be directly used for clinical purpose, through the interpretation of functional neuroimaging data.

## FROM LARGE-SCALE CEREBRAL NETWORKS

- Network of neuronal populations, anatomically interconnected through oriented axon bundles

- Parallel and overlapping **sub-networks** implement perceptive, motor and cognitive functions

- **Adaptive** mechanisms at different **time** scales (habituation and learning)

- The brain can be considered as an **uncertain** system, due to the involved complex mechanisms

- Each region has its **own** information processing mechanisms, which may be **nonlinear**

- Small, well-located regions are dedicated to the processing of a **specific** piece of information at different levels of abstraction. The **activity level** and the **identity** of these regions provide therefore a **measure** and a **label** to the information

## TO LARGE-SCALE ARTIFICIAL NETWORKS

- Formalism based on **Dynamic Bayesian Networks** (DBN), the most adapted formalism considering **LSCN properties**

- Directed **networked** structure

- Explicit representation of **time**

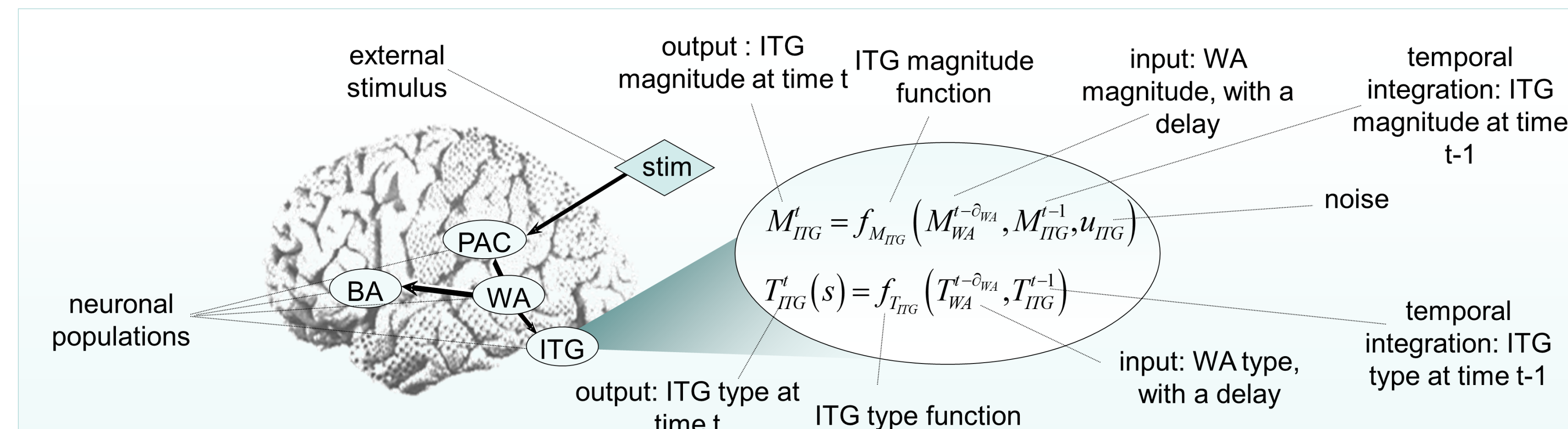
- Modeling of **uncertainty** through random variables

- **Causal and nonlinear** relationships

- **Differentiated** nodes

- **Specific information representation** with a numeric part (random variable) and a symbolic part (a deterministic variable), respectively called **magnitude and type**

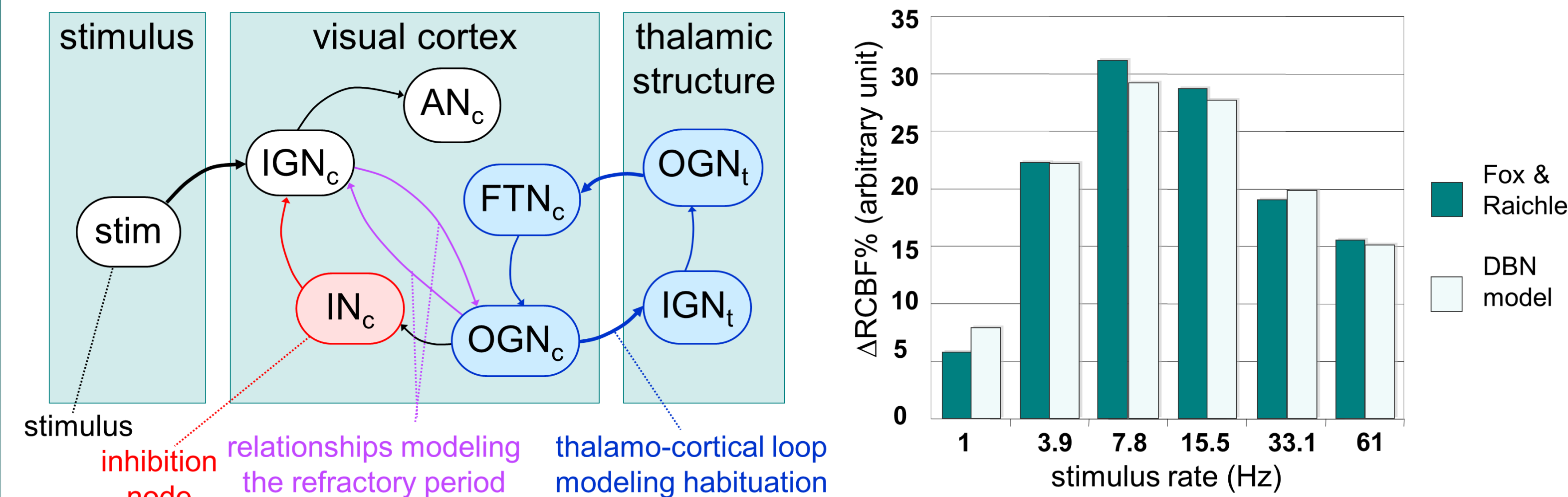
- **Specific propagation and learning** mechanisms, adapted to the information representation



## EXAMPLES

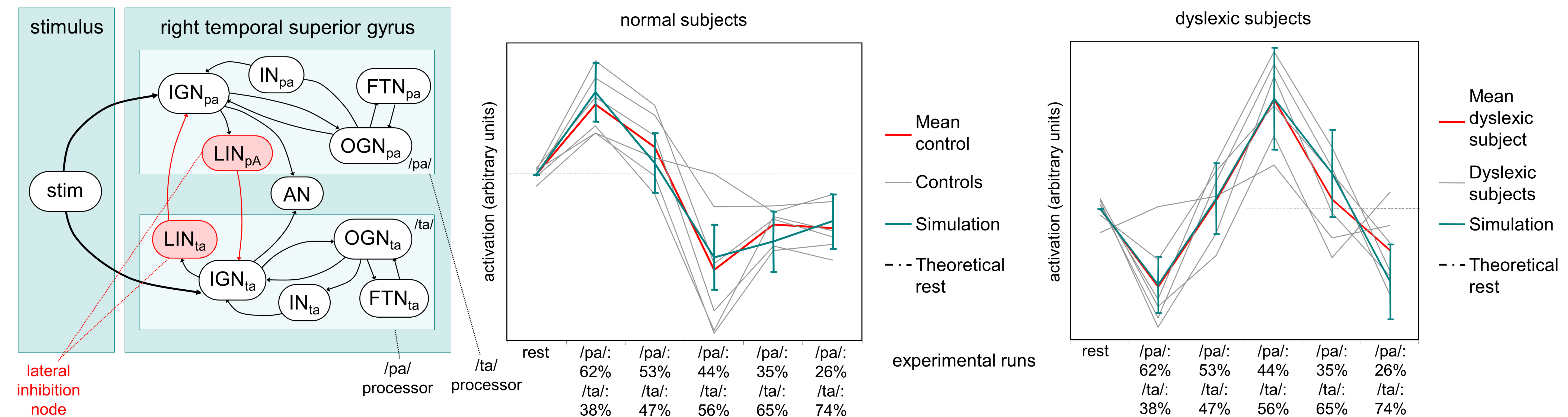
### COGNITIVE APPLICATION IN NORMAL SUBJECTS

- PET study by Fox & Raichle (1985)
- Visual stimulus rate modulates visual cortex activation: activation grows until 7,8 Hz, then fades and becomes stable → why ?
- Model involving the striate cortex (primary visual cortex) and the thalamus
- Hypotheses implemented in the model : habituation and refractory period at the regional level



### CLINICAL APPLICATION IN DYSLEXIC AND NORMAL SUBJECTS

- fMRI study by Ruff *et al.* (2001)
- Phonemic discrimination process between two phonetically close syllables /pa/ and /ta/: differences between normal and dyslexic subjects activations → why ?
- Model of the right temporal superior gyrus (early processing of auditory stimuli)
- Hypotheses implemented in the model :
  - existence of two specialized phonemic processors, represented by two sub-networks
  - near no lateral inhibition in dyslexic subjects



## CONCLUSION

### CURRENTLY

- New formalism able to process uncertain labeled information
- Interpretation of data provided by various neuroimaging techniques and concerning various tasks
- Open to evolutions of the knowledge in neuropsychology and neurophysiology.

### PERSPECTIVES

- Inclusion of more biological plausibility
- Make the models independent of the used data acquisition technique by using interface models able to translate cerebral information processing variables into neuroimaging results
- Application to complex systems such as ecological systems (tracing of pollutants, of populations), industrial systems (trace of different components during the building of a product), etc...

### REFERENCES

- P. T. Fox and M. E. Raichle, "Stimulus rate determines regional brain blood flow in striate cortex," *Ann Neurol*, vol. 17, pp. 303-5, 1985.
- Ruff S., Boulanouar K., Cardebat D., Celsis P., Demonet J. F. Brain correlates of impaired categorical phonetic perception in adult dyslexics. *Neuroimage* 2001;13(6):S595-S.