



# Modeling the cerebral activity with dynamic probabilistic networks

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# Context

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- **cognitive/** **sensorimotor** functions implemented by **large-scale cerebral networks**
- networks **identified** with activation studies and neuroimaging data
- **how** the activation derives from the function performance is still largely unknown



# Goals

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- answer **how** activation derives from information processing in large-scale networks
- provide an explicit **modeling tool** for the **interpretation** of neuroimaging data

# Method

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**activation**

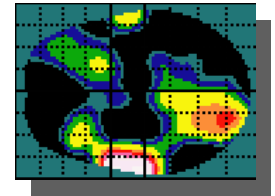
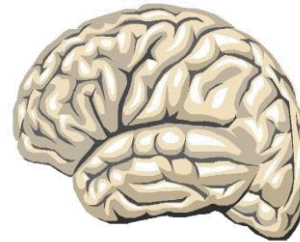
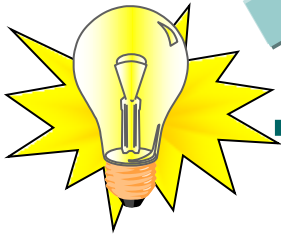


**simulation**

# Methods

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**activation**



**simulation**

**stimulation**

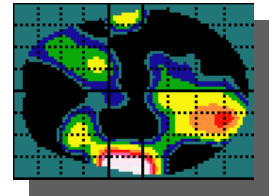
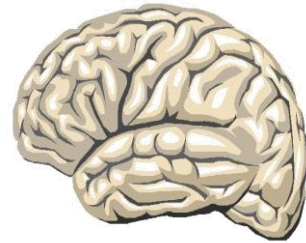
**stimuli  
perception**

**information  
processing**

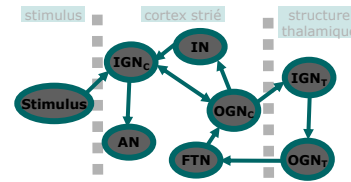
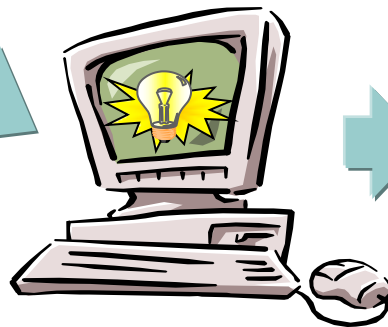
**observed  
activity**

# Methods

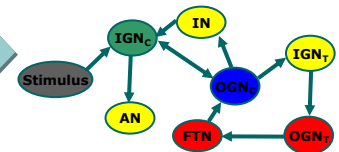
activation



simulation



Légende :  
=> lien fonctionnel  
=> lien structurel



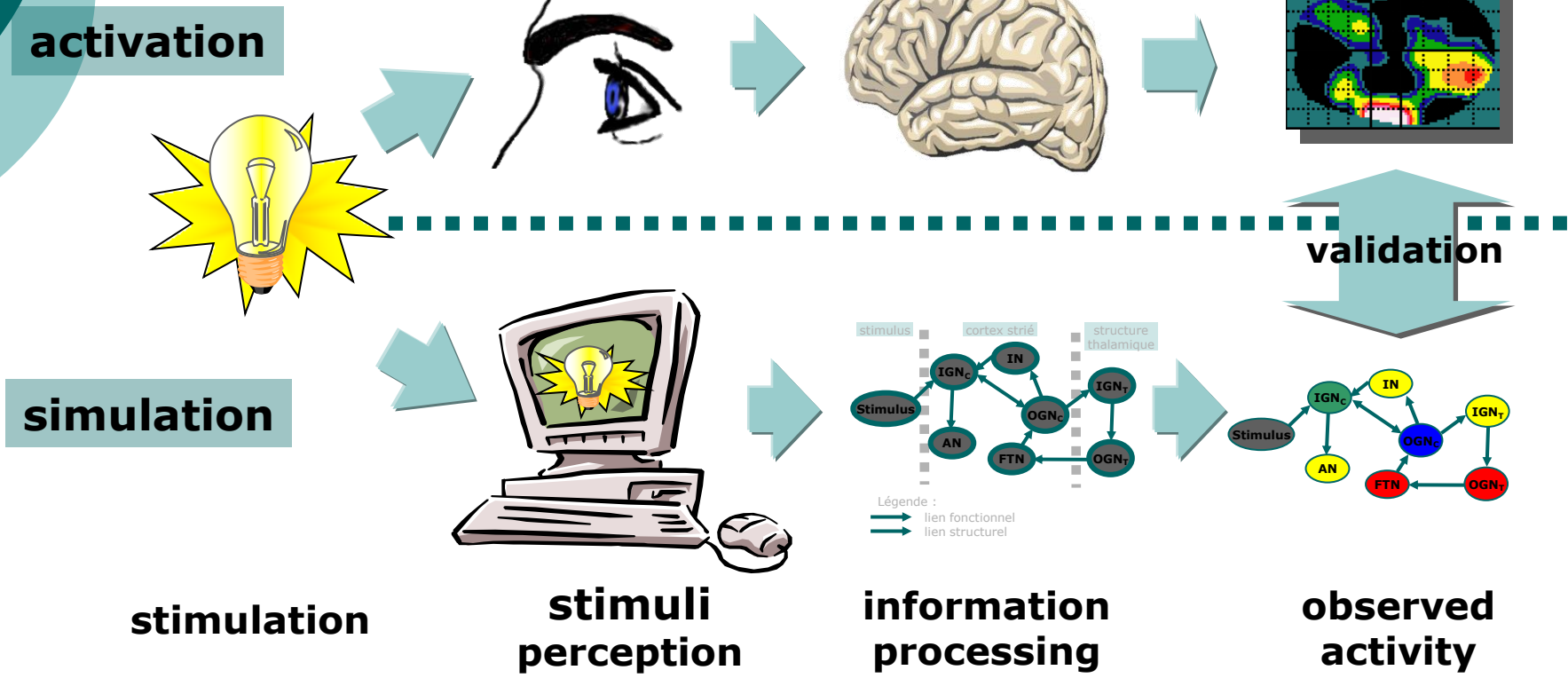
stimulation

stimuli  
perception

information  
processing

observed  
activity

# Methods





# Modeling tool

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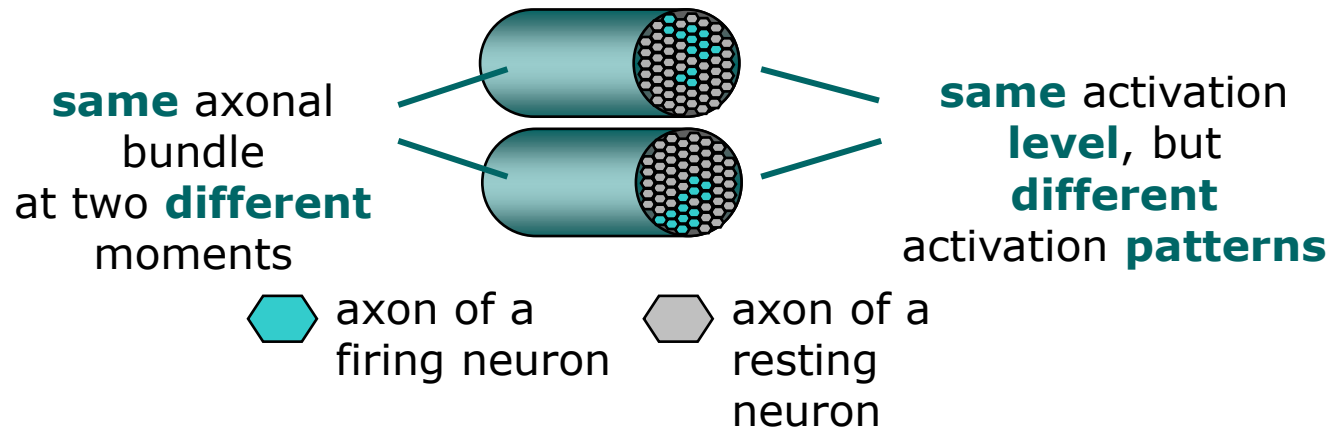
- based on **dynamic Bayesian networks**
- specific **information** representation
- specific **propagation** and **learning** mechanisms



# Modeling tool: information representation

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- **information** = abstraction of the neural population able to process it

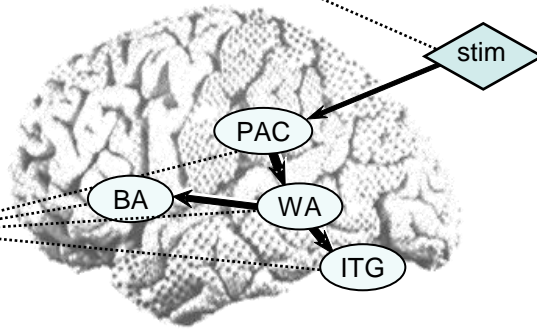


- **magnitude** : global activation **level**
- **type** : **pattern** of activated neurons

# Modeling tool: DBN

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external stimulus



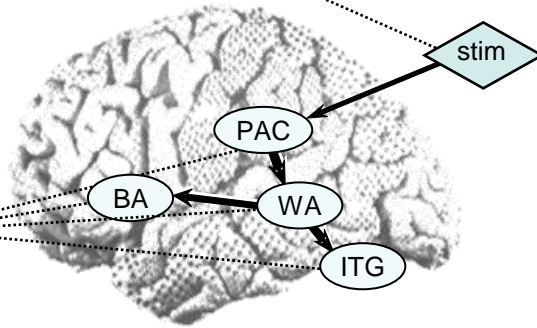
neuronal  
populations

- **directed** networked structure

# Modeling tool: DBN

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external stimulus



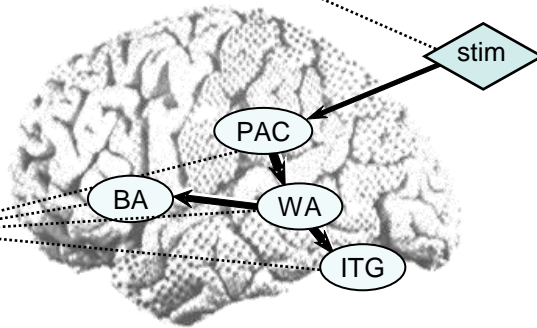
neuronal  
populations

- **directed** networked structure
- **probabilistic, causal and nonlinear** relationships

# Modeling tool: DBN

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external stimulus

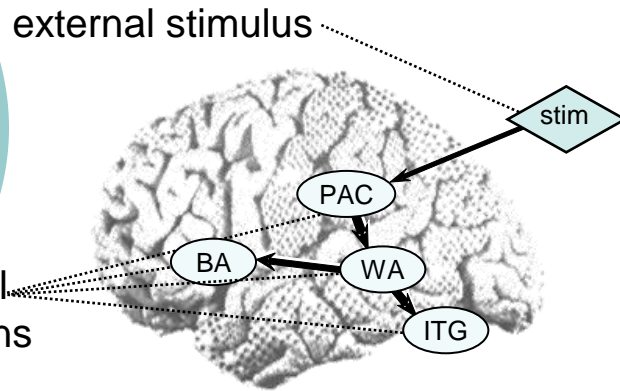


neuronal  
populations

- **directed** networked structure
- **probabilistic, causal and nonlinear** relationships
- **differentiated** nodes

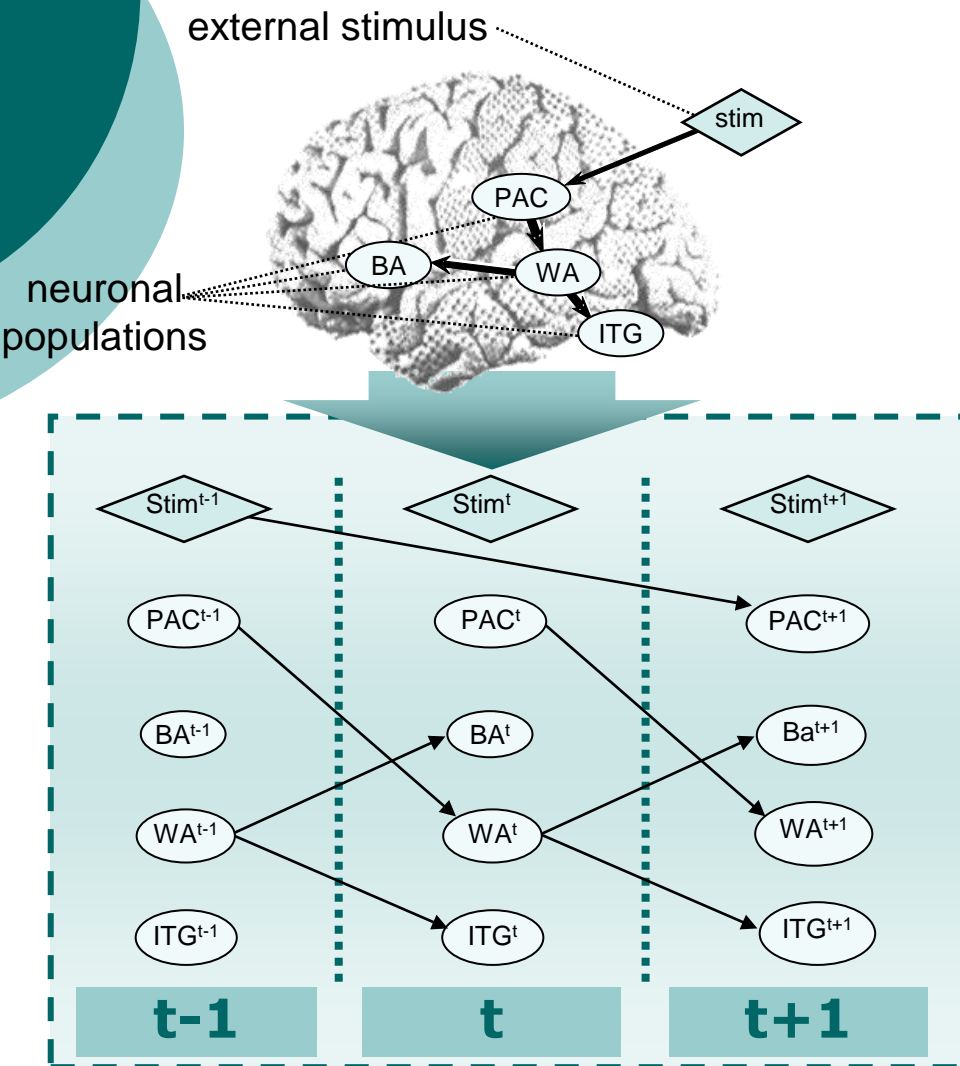
# Modeling tool: DBN

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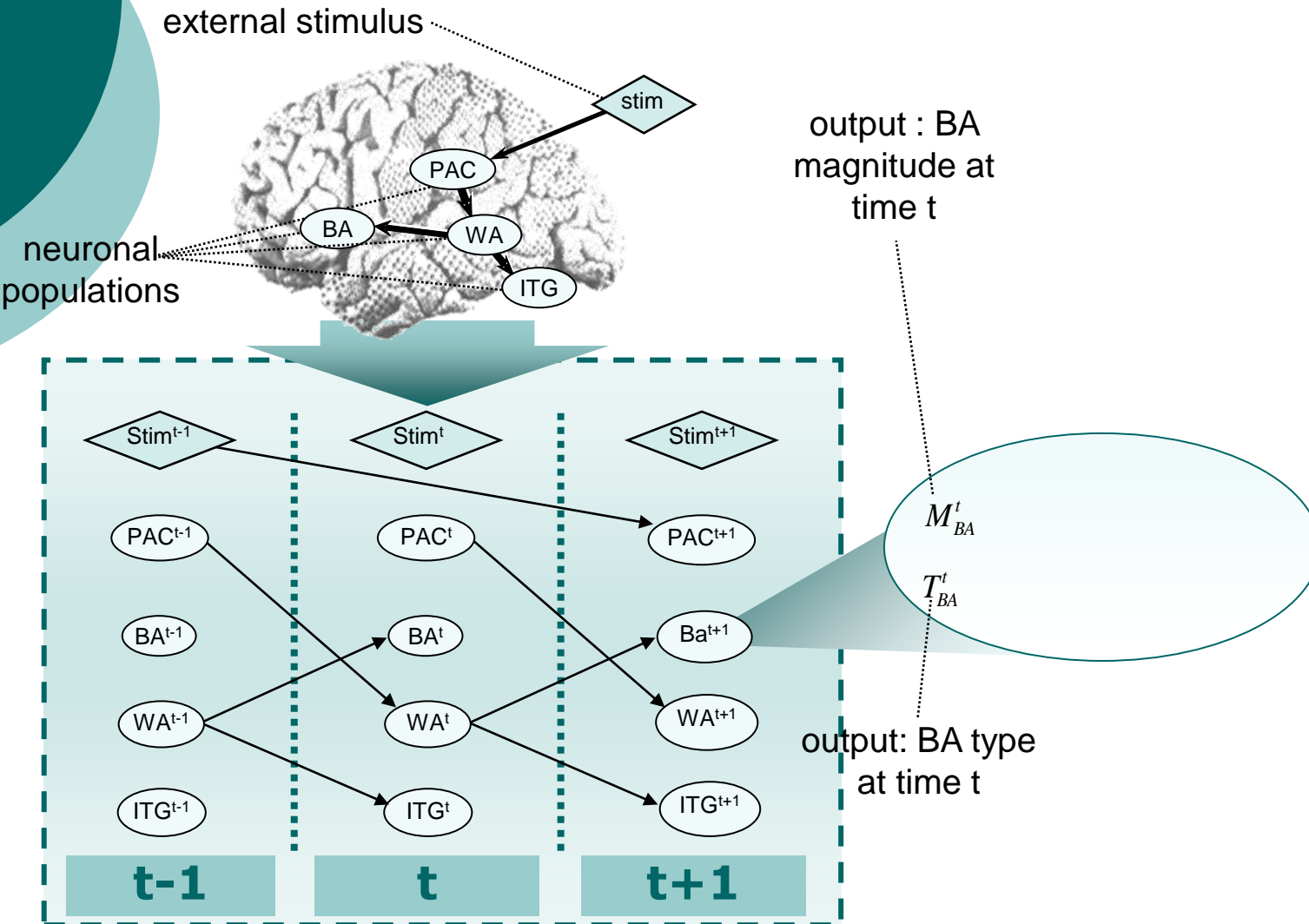
- **directed** networked structure
- **probabilistic, causal and nonlinear** relationships
- **differentiated** nodes
- **explicit and discrete** representation of **time**

# Modeling tool: DBN

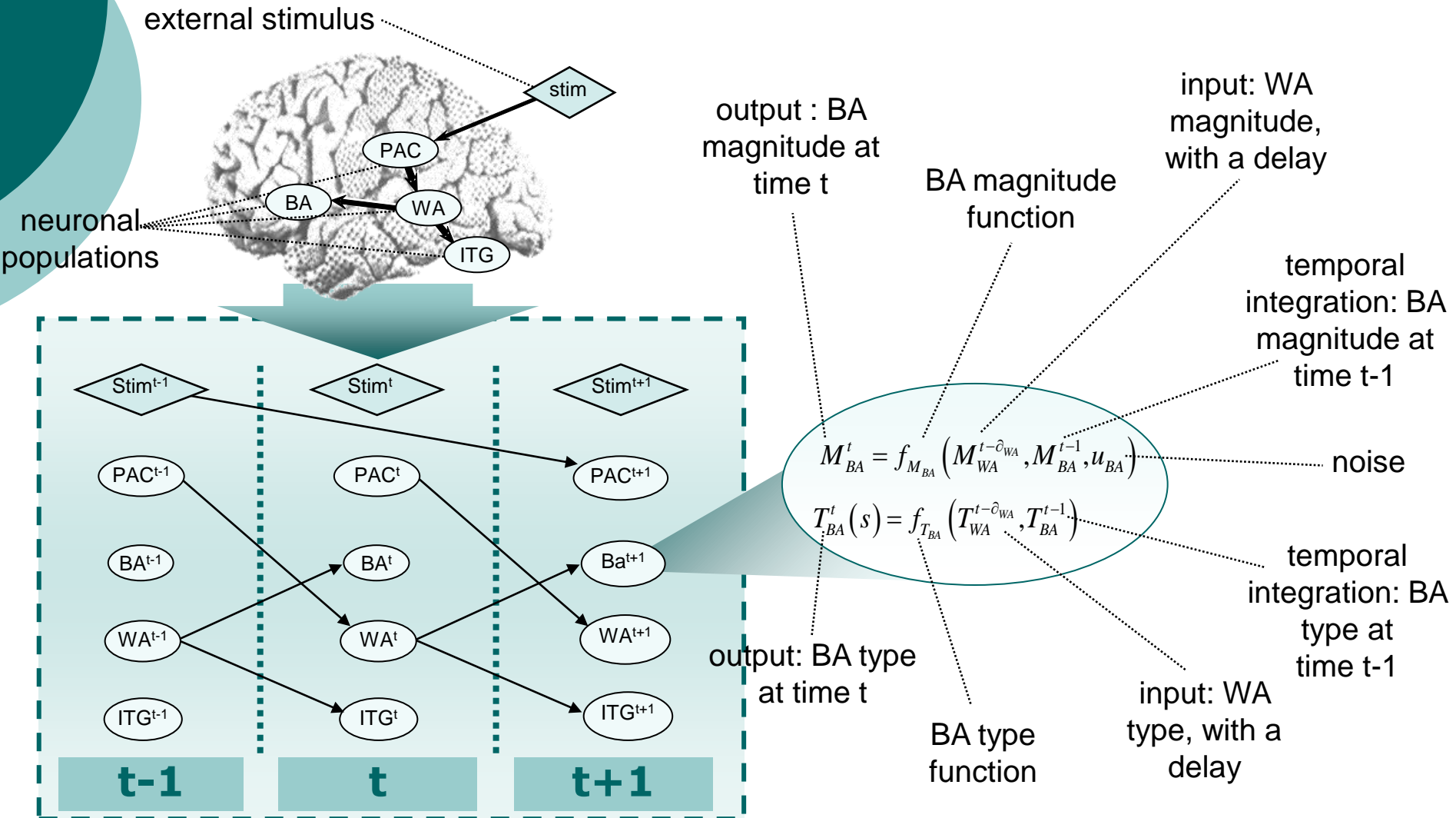


- **directed** networked structure
- **probabilistic, causal and nonlinear** relationships
- **differentiated** nodes
- **explicit and discrete** representation of **time**

# Modeling tool: LSAN



# Modeling tool: LSAN



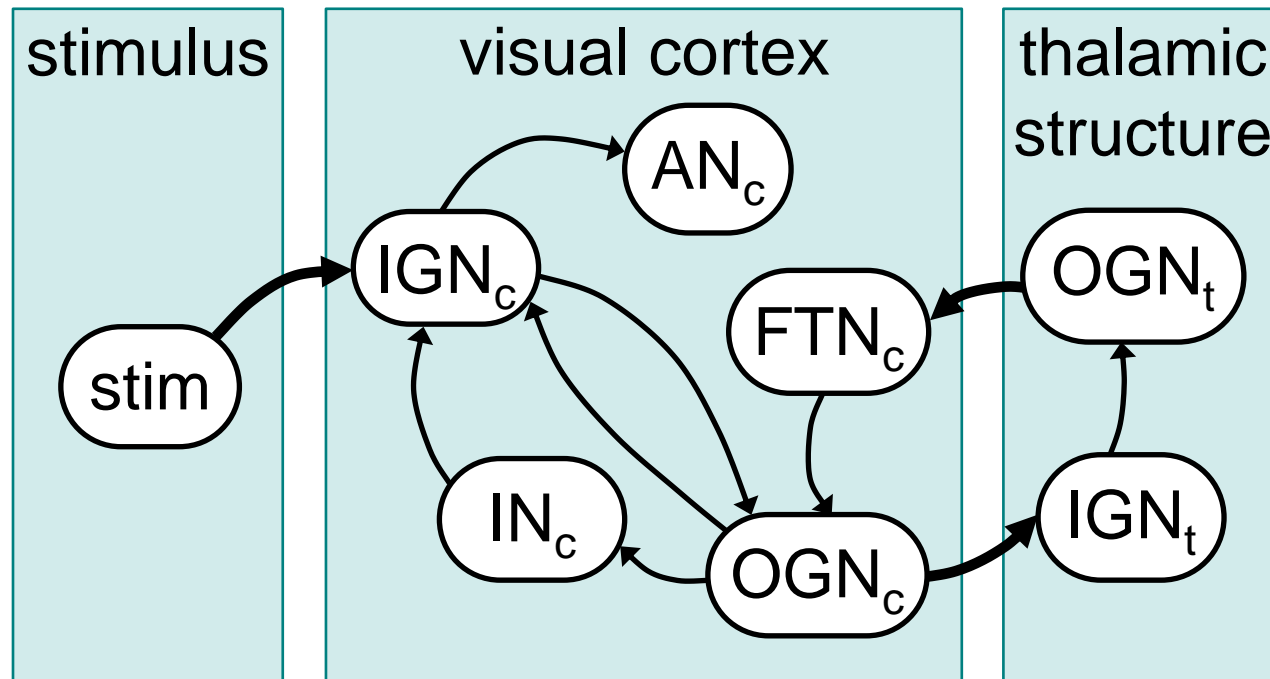


# A cognitive application: description

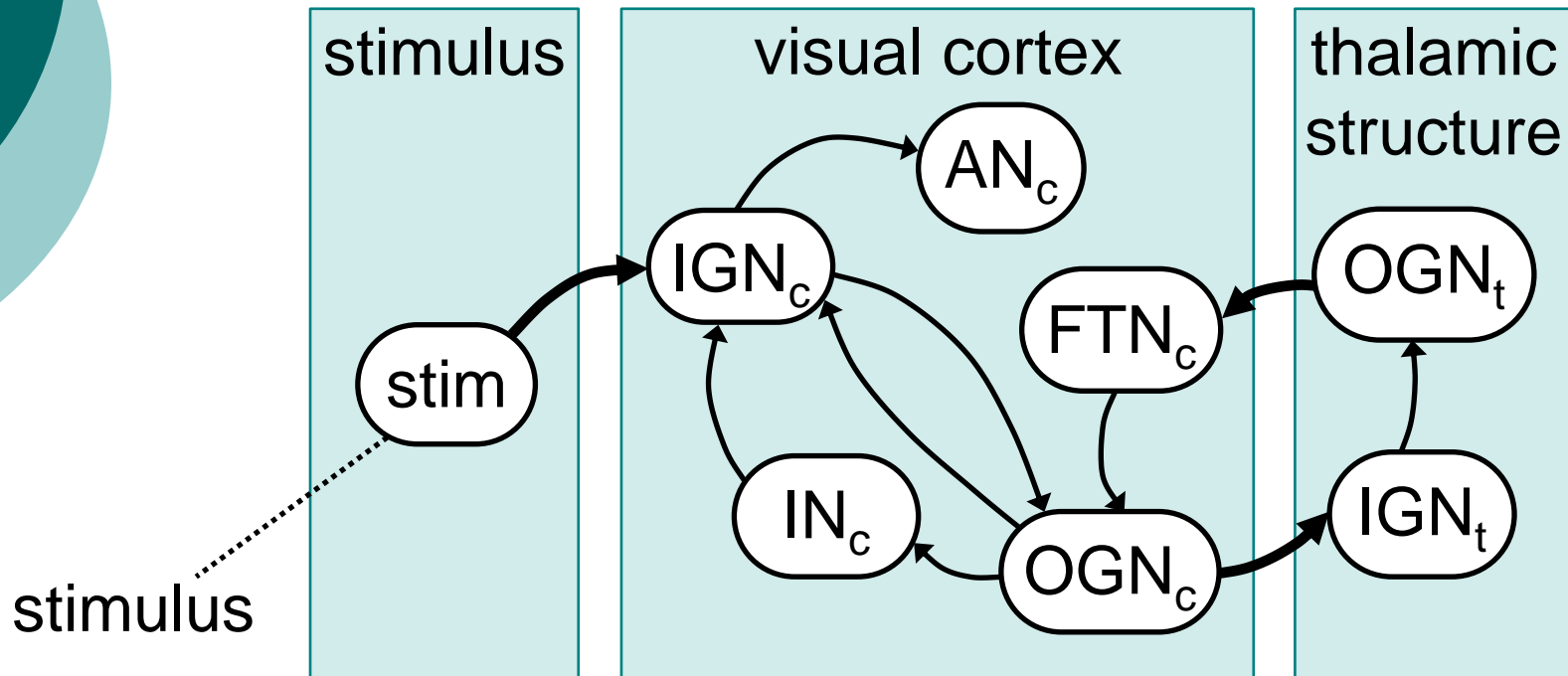
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- **PET** study by Fox & Raichle (1985)
- **Visual** stimulus rate modulates visual cortex activation: activation grows until 7,8 Hz, then fades and becomes stable  
> why ?
- Model involving the **striate cortex** (primary visual cortex) and the **thalamus**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

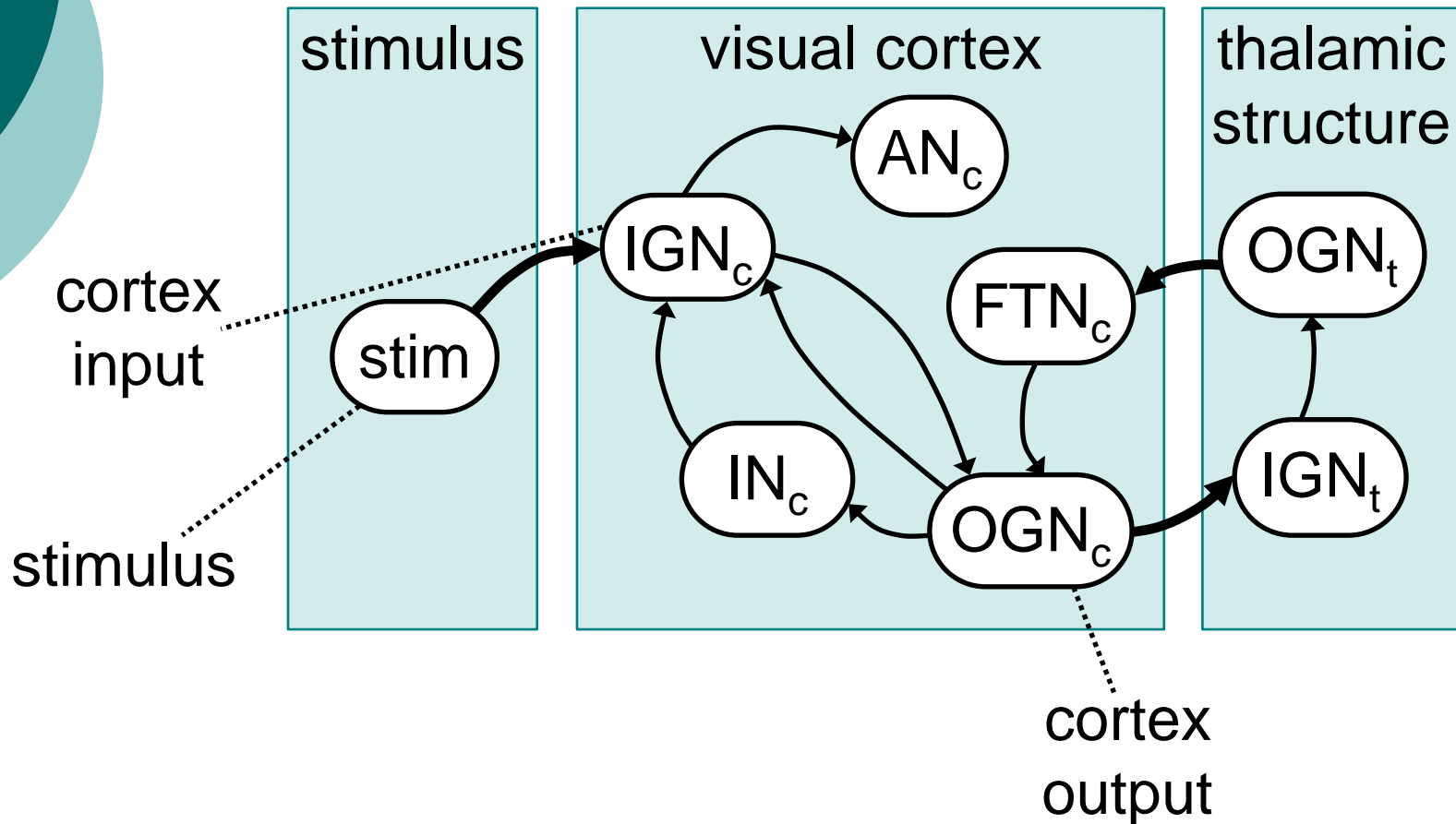
# A cognitive application: model



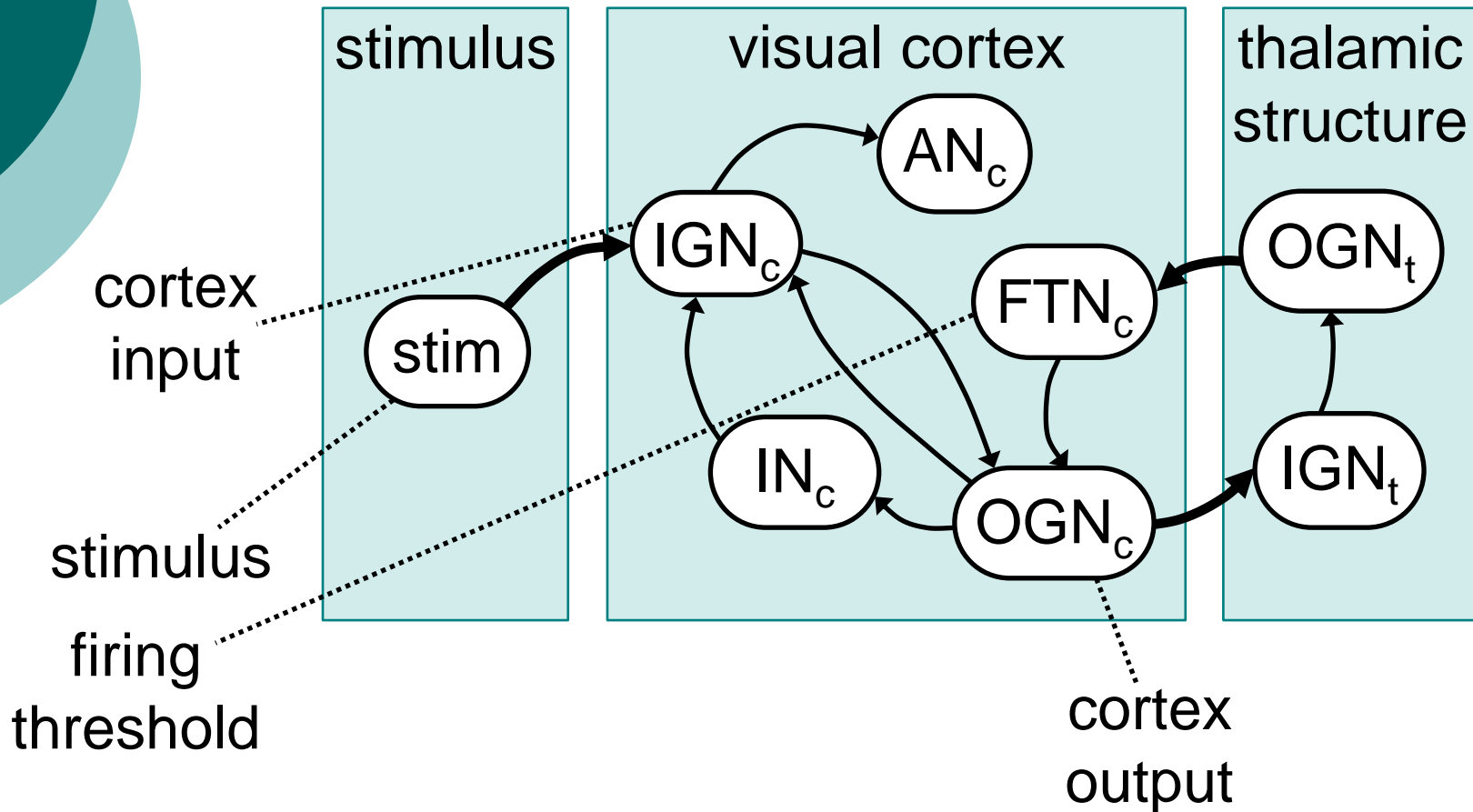
# A cognitive application: model



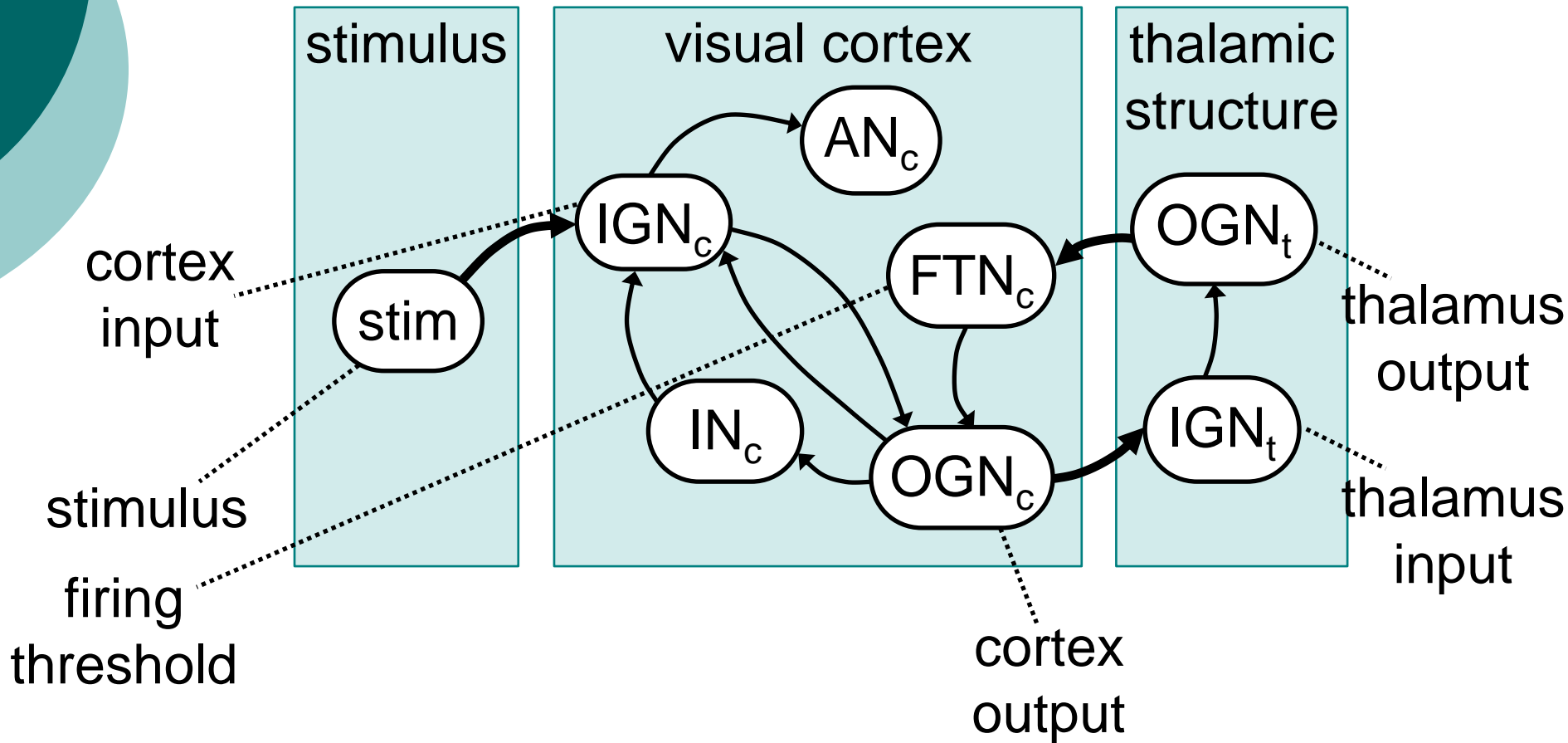
# A cognitive application: model



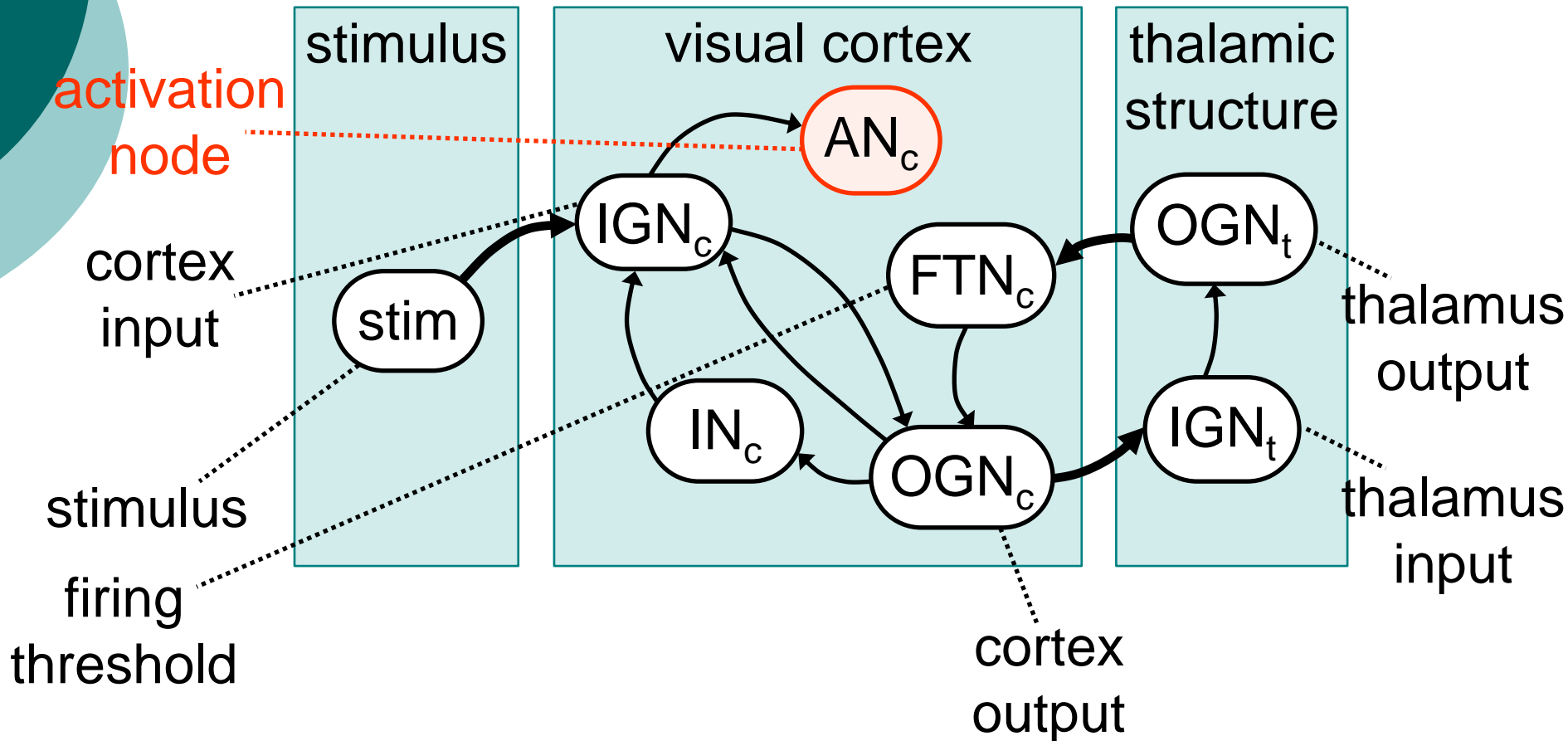
# A cognitive application: model



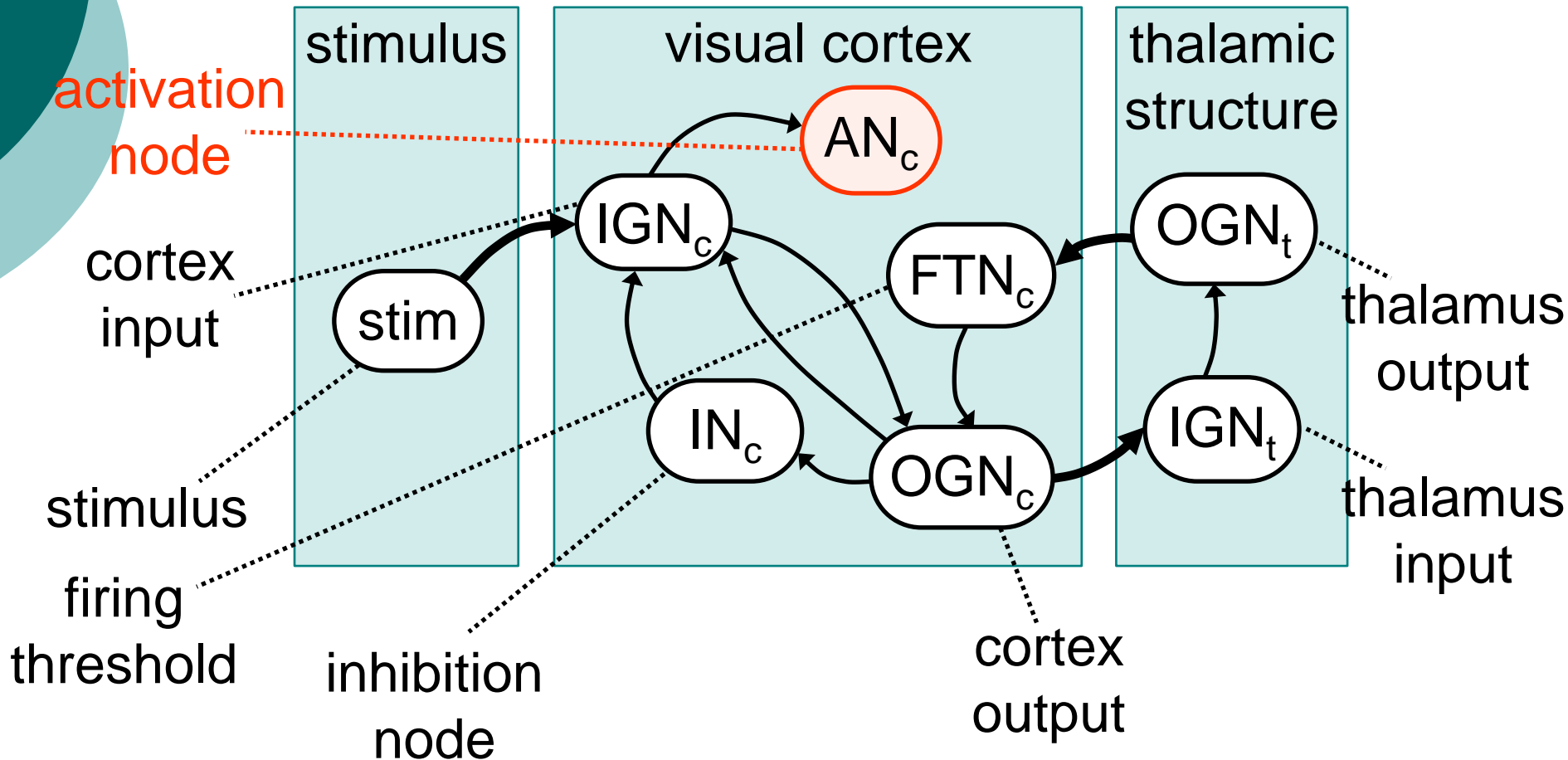
# A cognitive application: model



# A cognitive application: model

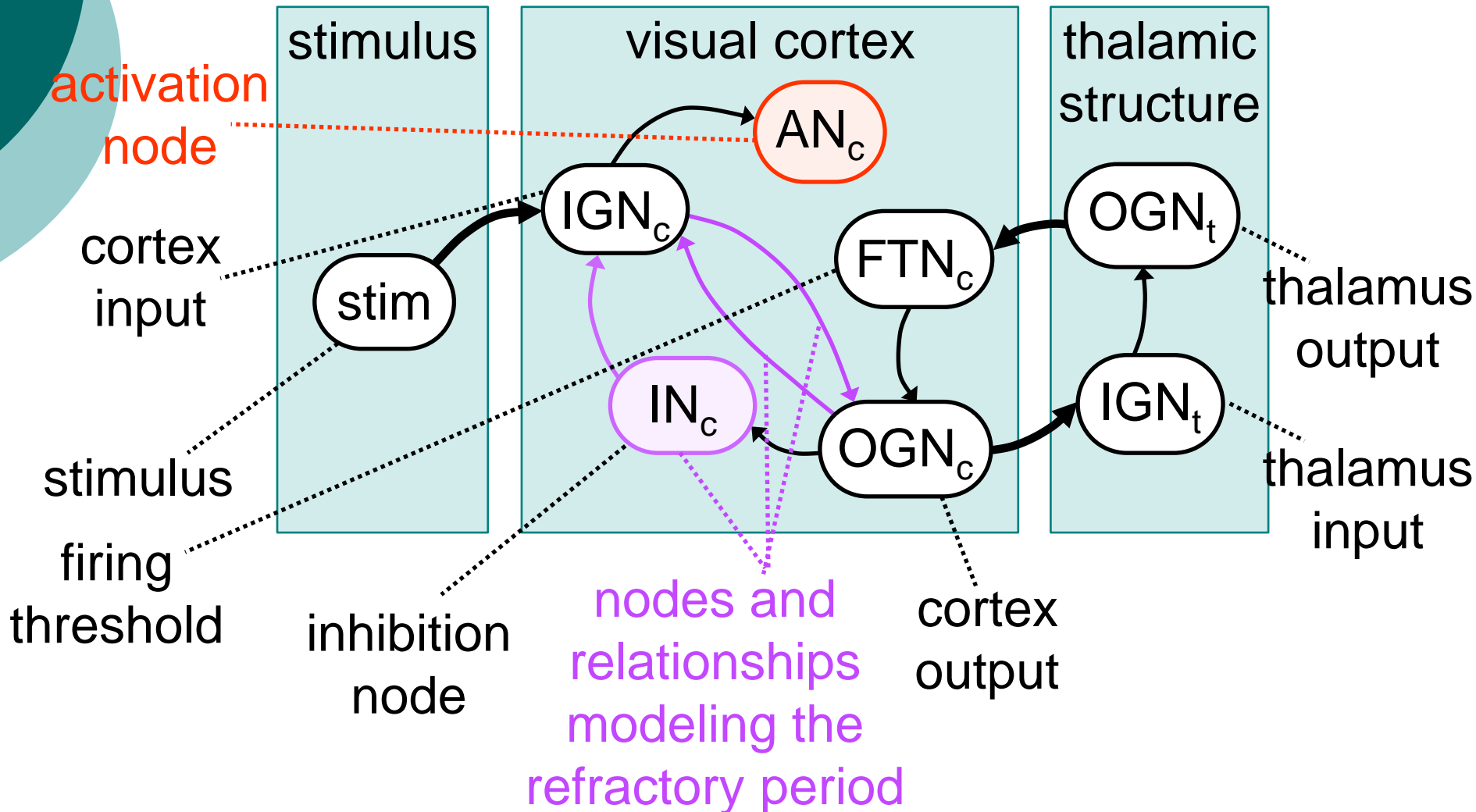


# A cognitive application: model

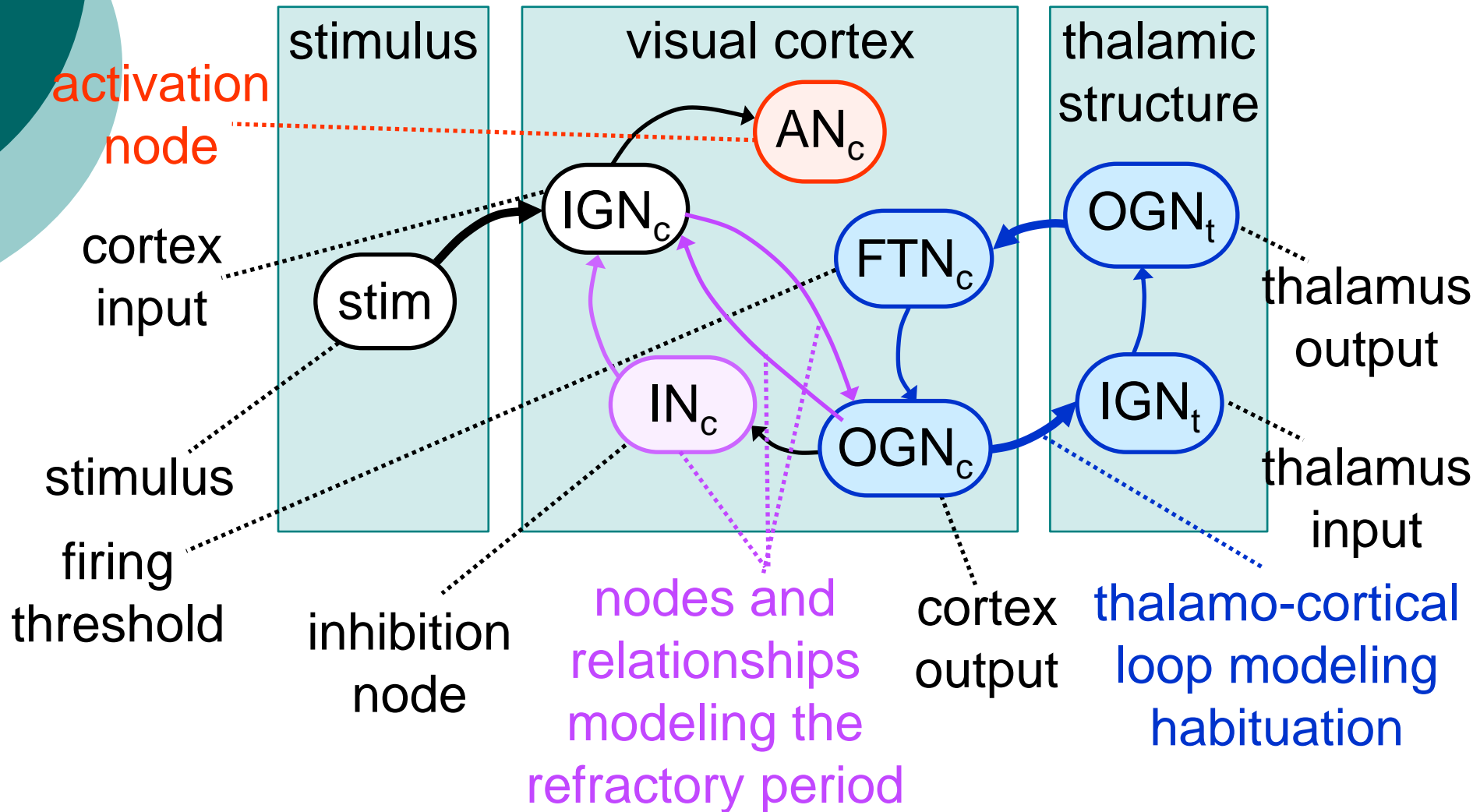




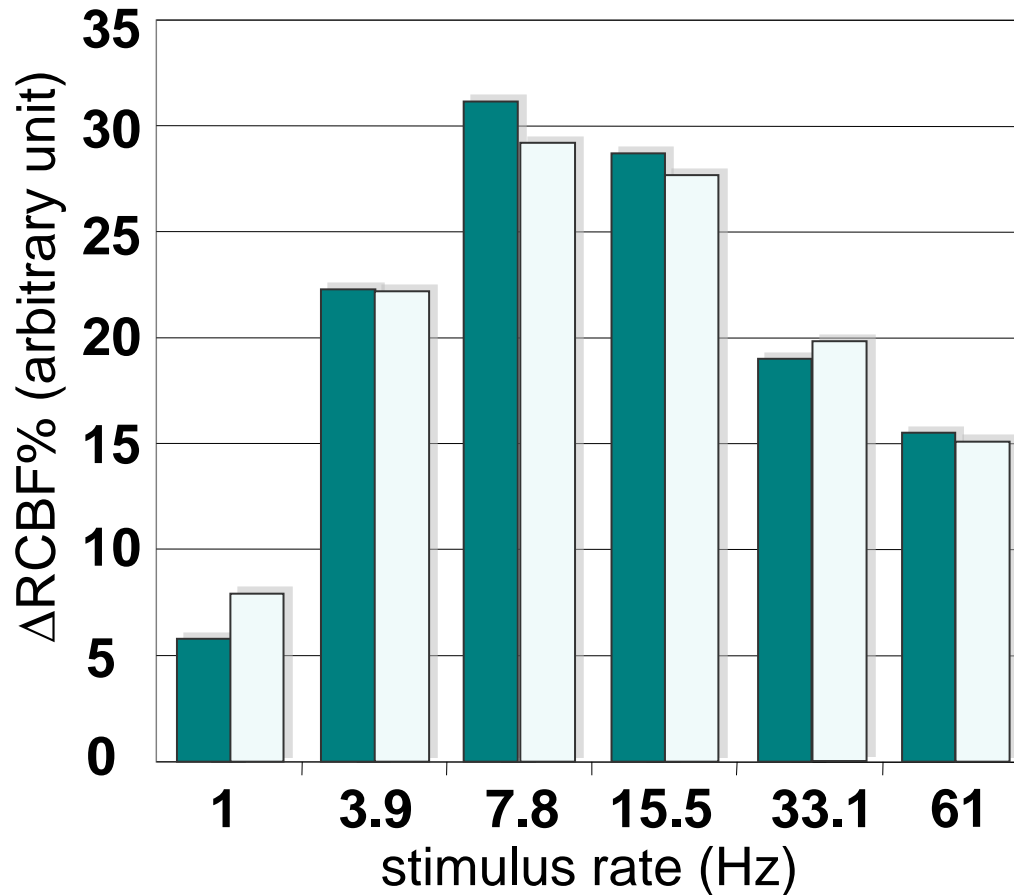
# A cognitive application: model



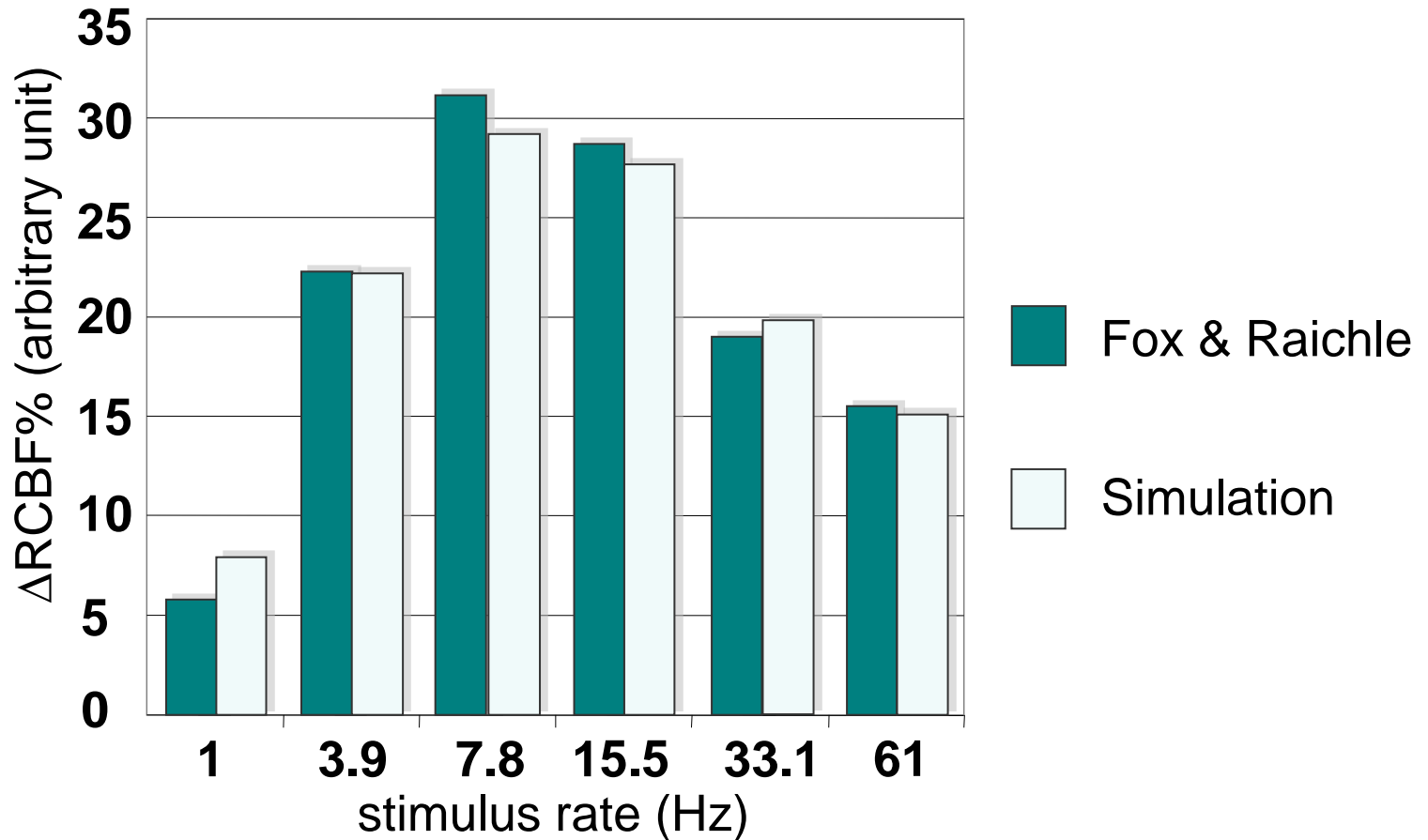
# A cognitive application: model



# A cognitive application: results



# A cognitive application: results



# A clinical application: description

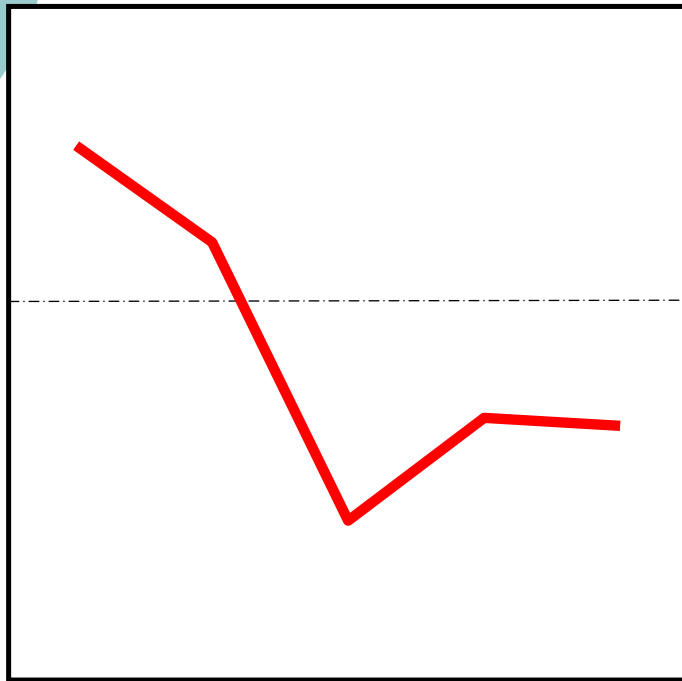
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- **fMRI** study by Ruff *et al.* (2001)
- **Phonemic categorization** process between two phonetically close syllables /pa/ and /ta/: differences between **normal** and **dyslexic** subjects activations > why ?
- Model of the **right temporal superior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

# A clinical application: results

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normal subjects



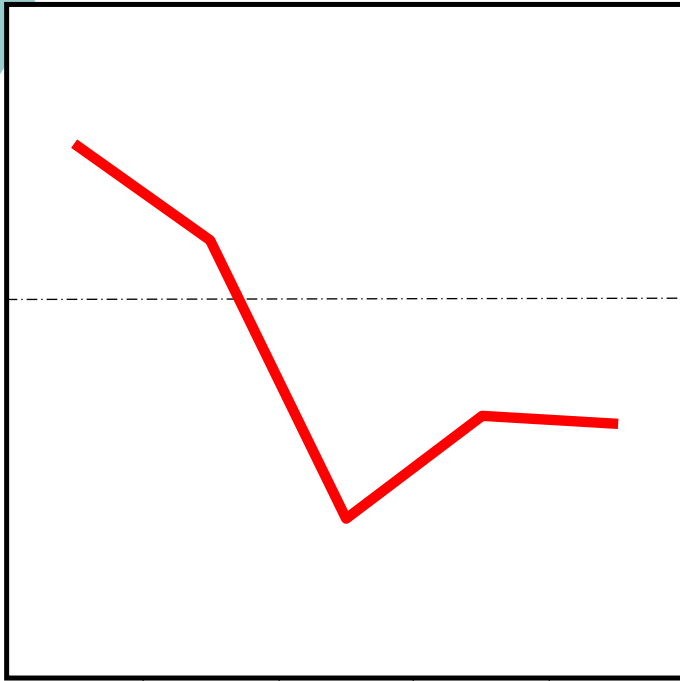
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62% 53% 44% 35% 26%

# A clinical application: results

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normal subjects

activation (arbitrary units)



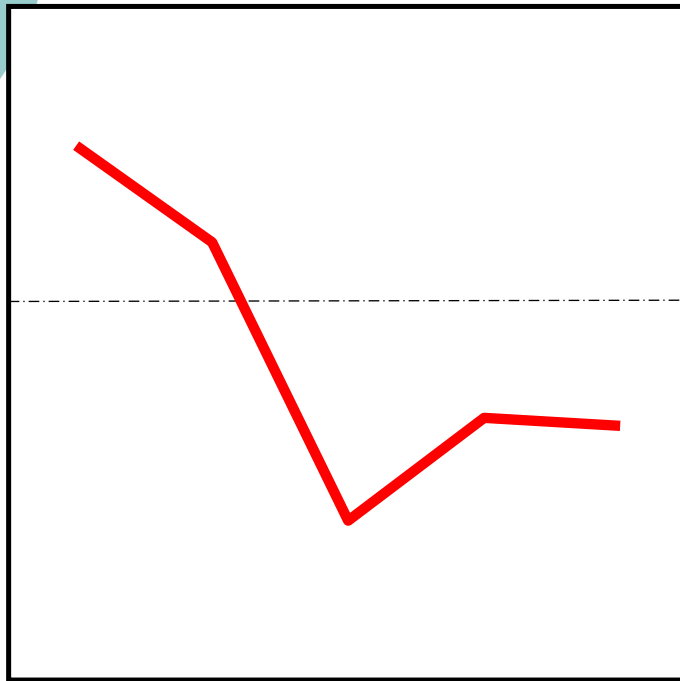
runs

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# A clinical application: results

normal subjects

activation (arbitrary units)



--- Theoretical rest  
— Experiment

runs

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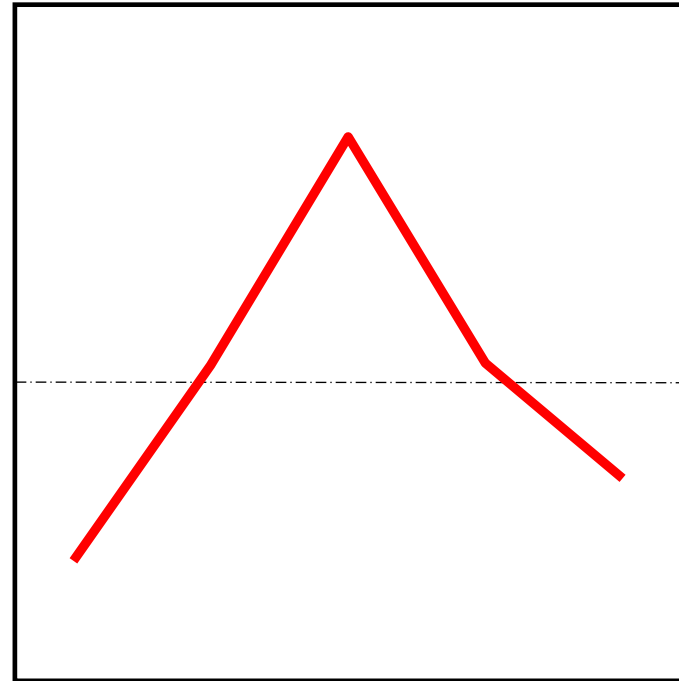
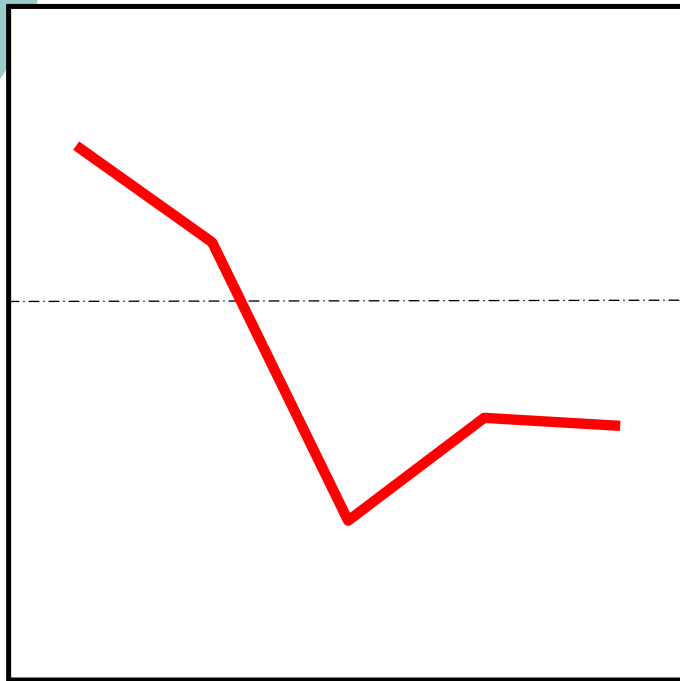


# A clinical application: results

normal subjects

dyslexic subjects

activation (arbitrary units)



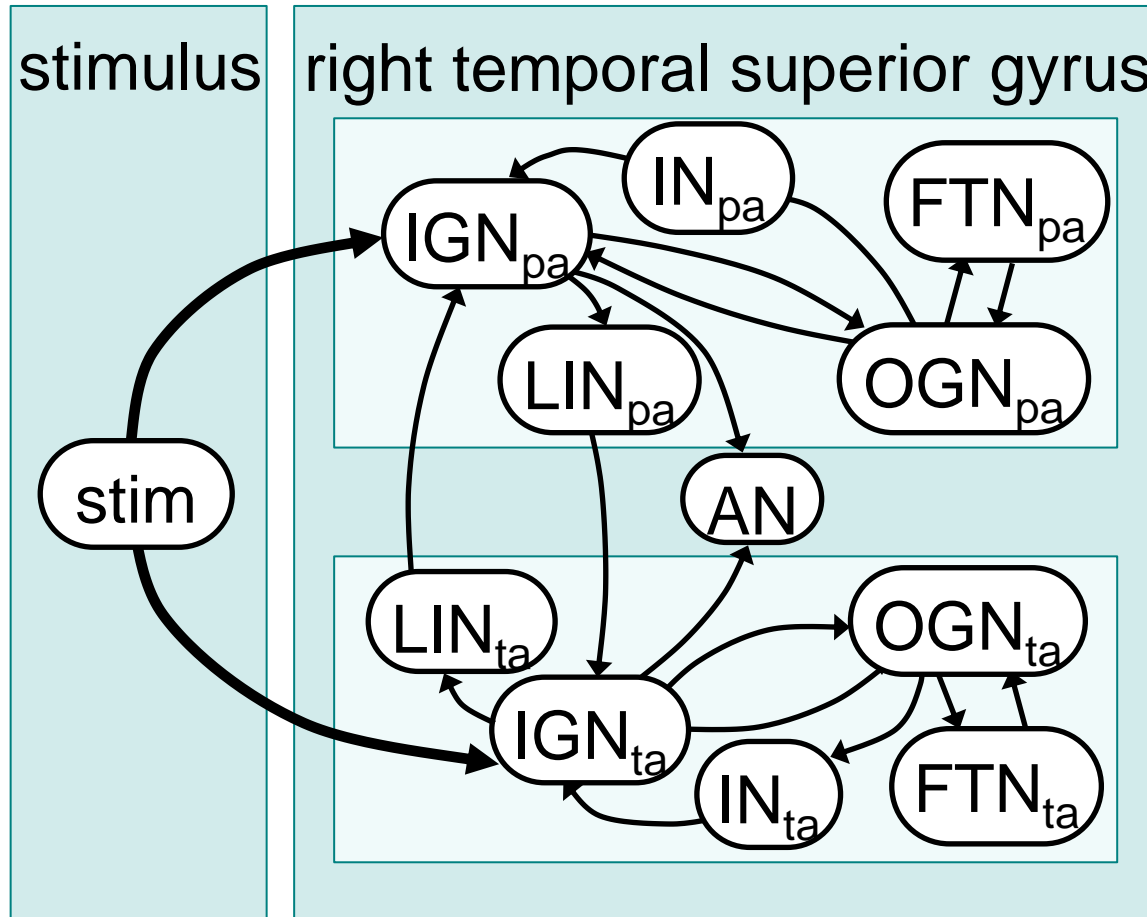
--- Theoretical rest  
— Experiment

runs

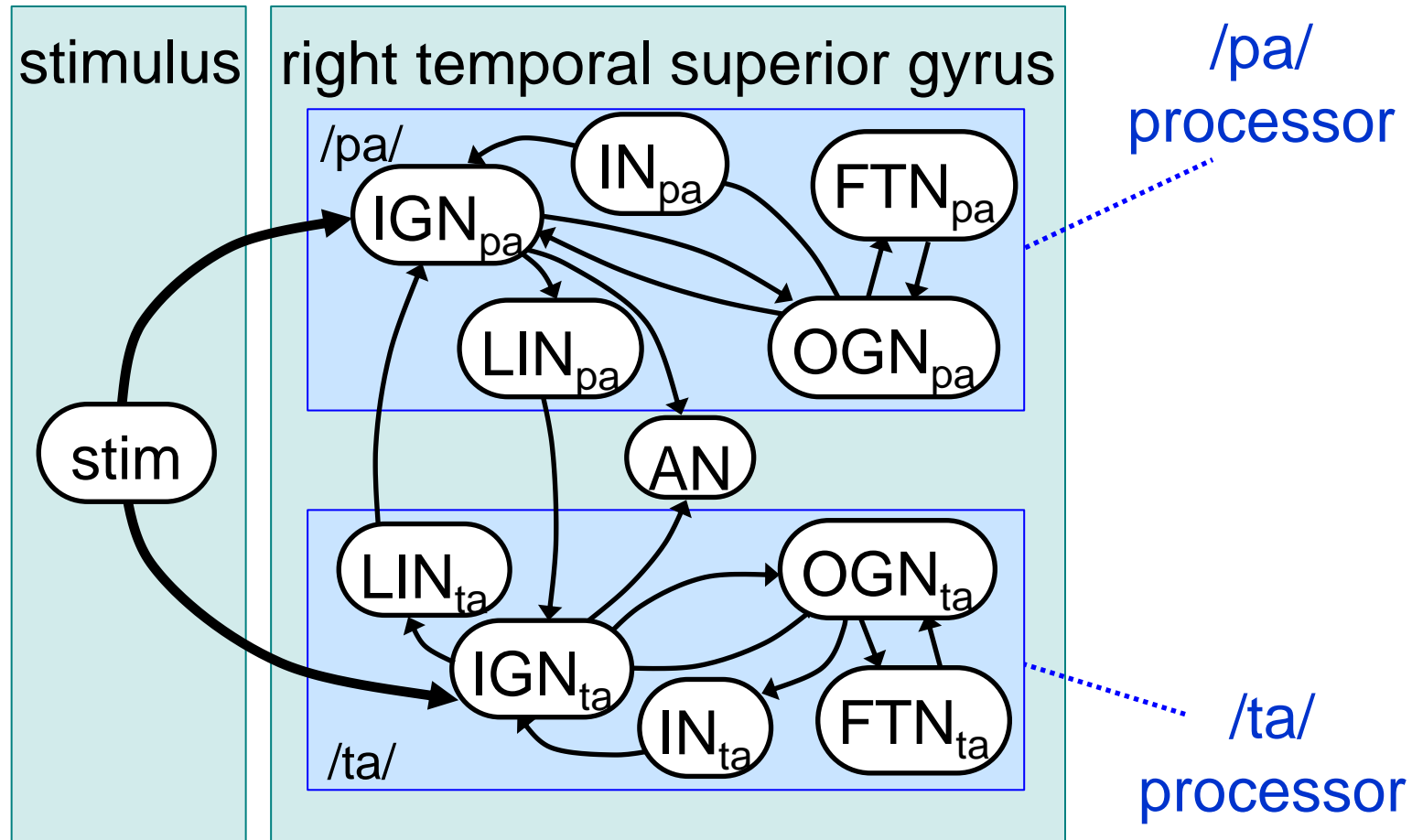
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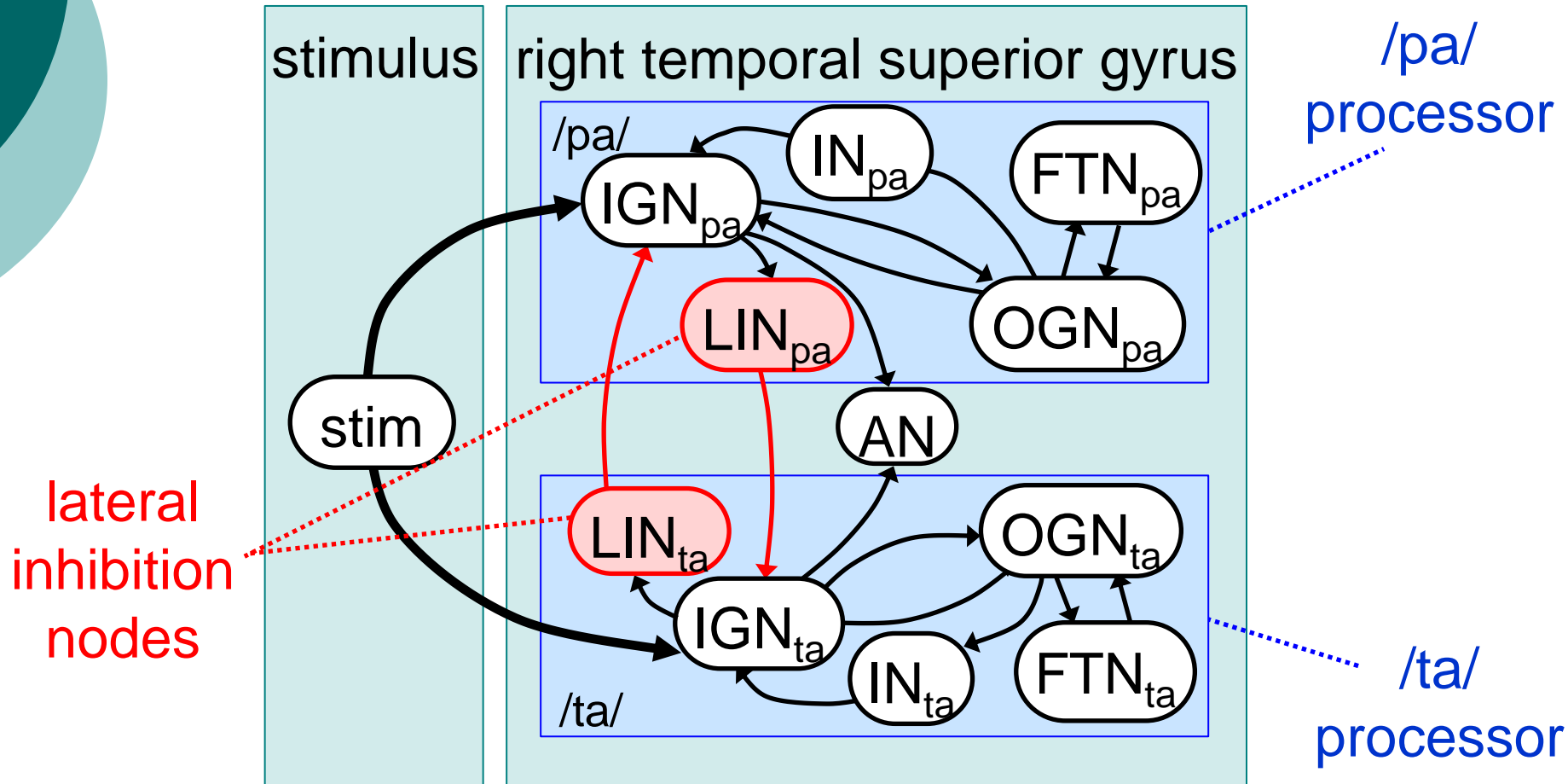
# A clinical application: normal model



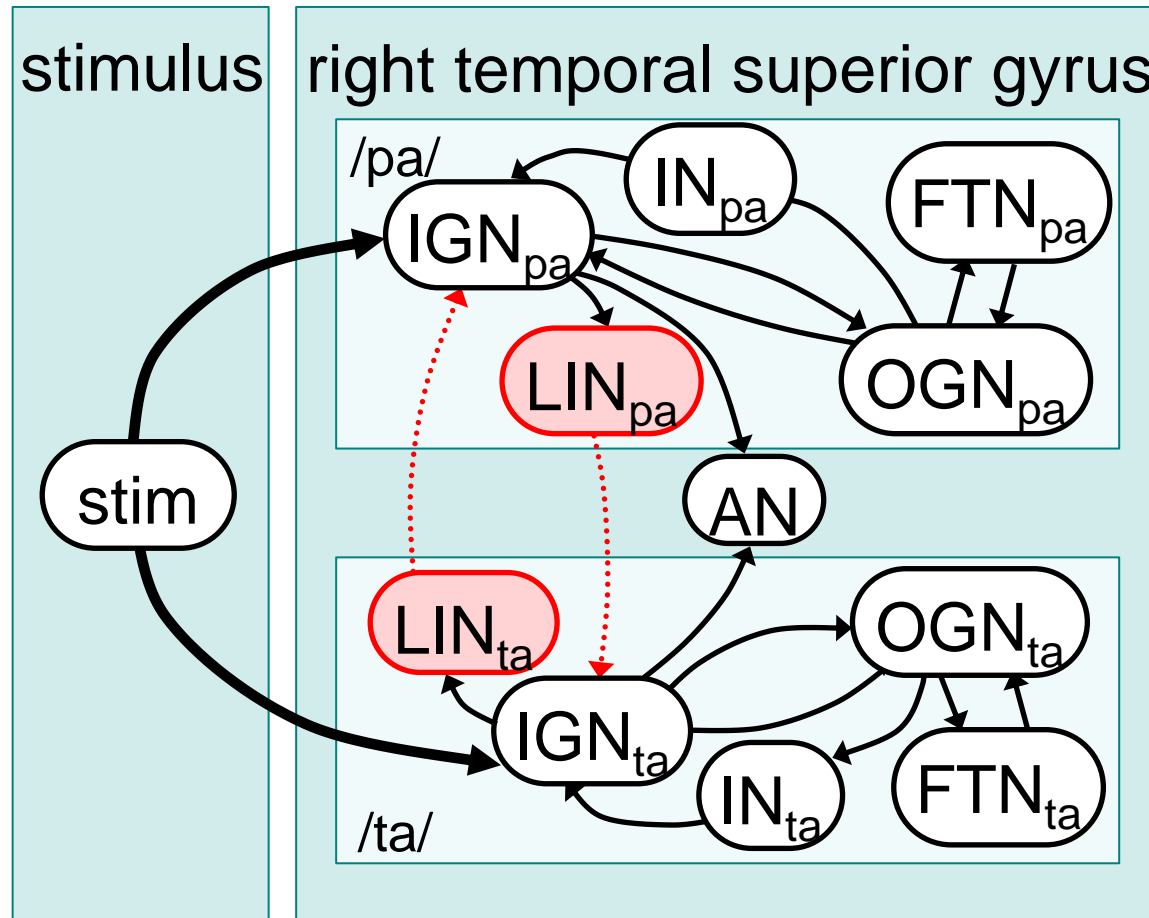
# A clinical application: normal model



# A clinical application: normal model



# A clinical application: dyslexic model

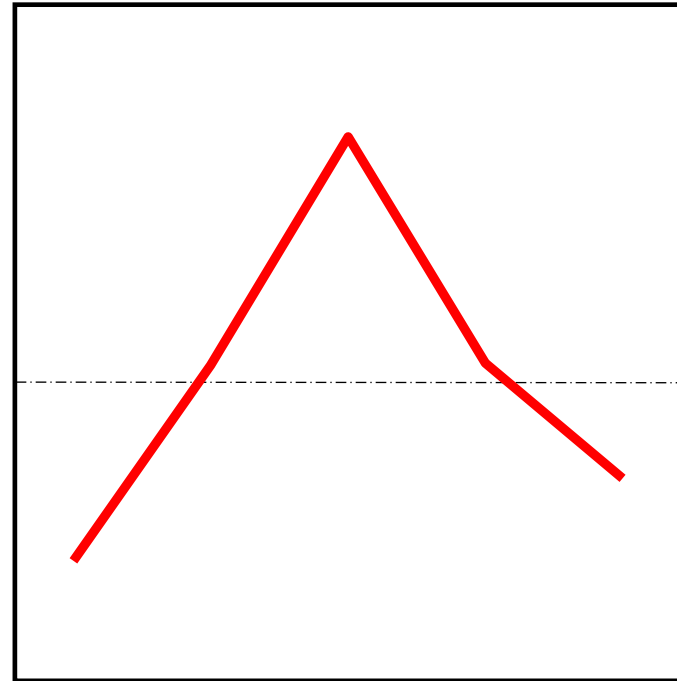
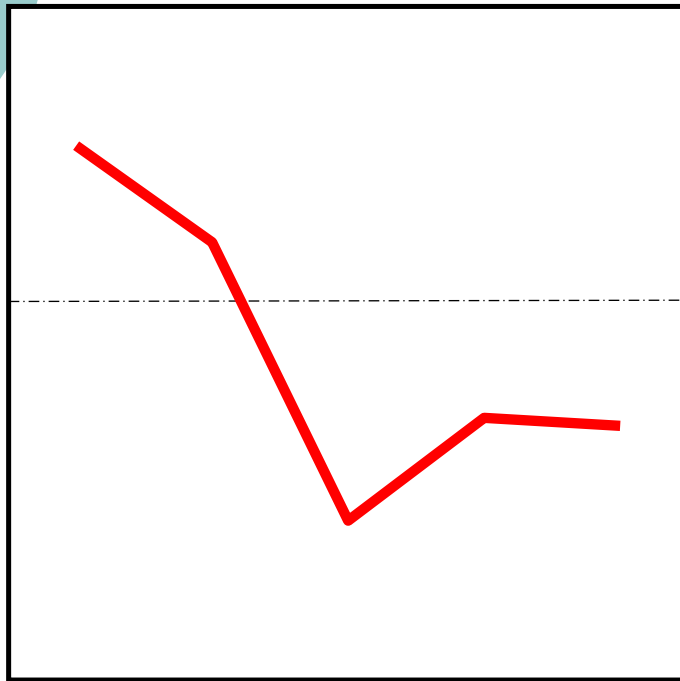


# A clinical application: results

normal subjects

dyslexic subjects

activation (arbitrary units)



--- Theoretical rest  
— Experiment

runs

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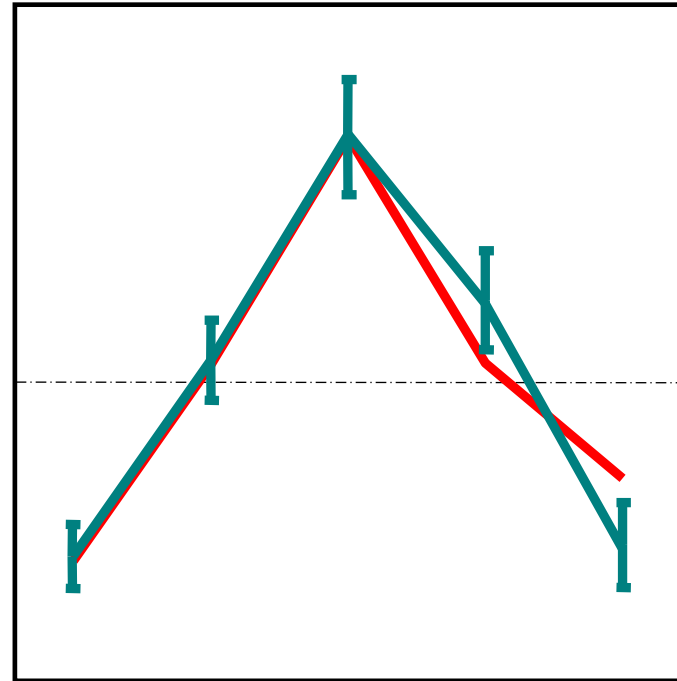
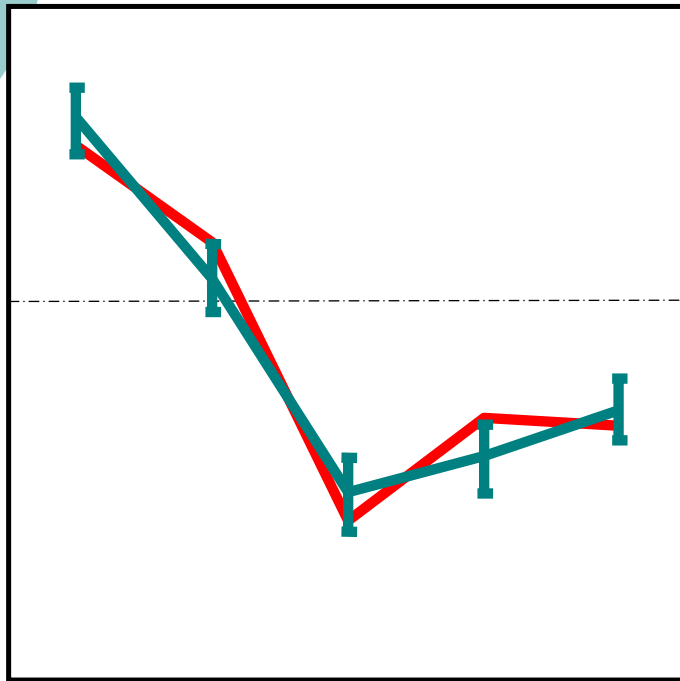
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# A clinical application: results

normal subjects

dyslexic subjects

activation (arbitrary units)



- - Theoretical rest  
 — Experiment  
 — Simulation

runs

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62% 53% 44% 35% 26%

# Perspectives

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- 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