

The Global Workspace

Bernard Baars, 1988, 1997, 2002.

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Background

In many respects, there is a strong contrast between the organization of the brain and that of consciousness

Brain

- **Billions of neurons, firing at an average rate of 40 nerve impulses/sec**
- **Dense interconnections: we can reach any single neuron from any other in less than seven steps!**
- **Processing is massively parallel and highly distributed**
- **Many specialized processors or modules that operate in a largely independent, fast, automatic, often mandatory, and inflexible fashion**
- **We could speak of a 'society of modules'**

Brain: specialized modules

- **Examples of specialized modules in reading:**
 - **letter and word identification**
 - **letter-to-phoneme mapping**
 - **eye-movement control**
 - **linguistic analyses such as**
 - **matching words to a mental lexicon**
 - **syntactic analysis**
 - **semantic analysis**

Brain: specialized modules

- **Important:**
These specialized modules operate unconsciously
- call them USMs
(unconscious specialized modules)**

The Stroop effect:

Blue

Red

Green

Red

Blue

Green

Red

Blue

Green

Consciousness

- **In contrast to the USMs, consciousness**
 - **is slow** (calculate $15 \times 15 \times 15$)
 - **is serial** (contents enter consciousness one-by-one)
 - **has limited capacity** (we can be conscious of only one content, e.g. one of two simultaneous spoken stories; one ball game on screen; only the currently rehearsed item in WM; we can execute only one action that demands consciousness)
 - **is flexible** (can adapt to novel situations)
 - **is context-sensitive** (responses can be adapted to context)
 - **is relational, associative** (can establish links between any two conscious contents → classical conditioning!)

What architecture could explain these largely opposite properties of the brain and consciousness?

**Baars' answer:
A Global Workspace**

Global workspace (GW)

- **The idea: Consciousness is a global workspace that serves to exchange and distribute information between different brain processors**
- **Consciousness = central information exchange of the brain, the publicity organ of the brain**
- **Consciousness makes information globally available for all the unconscious specialized modules and other brain processes**
- **Consciousness creates access to many (all?) brain processors**

Consciousness creates access

- **Simply by being conscious, information gains access to the vast collection of unconscious brain resources, such as USMs, memory stores etc.**
- **This is impressively demonstrated in (associative) learning: Simply by relating two (or more) items in consciousness, we learn them. Consciousness of something is all that is required to learn it. Completely unconscious learning, on the other hand, does not seem to be possible.**
- **Similarly, simply by consciously looking at pictures, we gain access to and can store them in the vast memory system of our brain**

Consciousness creates access

- **By simply being conscious of a problem, we access the problem-solving machinery of our brain, which will unconsciously deal with the problem, and, if we're lucky, come up with a solution and present it to consciousness**
- **Another impressive demonstration of global access is the fact that conscious biofeedback enables access to virtually every brain system, from alpha waves to single neurons**

Global workspace

- **On the input side, many contents, inputs, or stimuli compete for access to the global workspace= consciousness, but only one content at a time can become conscious**
- **→ limited capacity, serial, slow**
- **Attention is the mechanism that selects which content gets access to consciousness**

potentially conscious contents

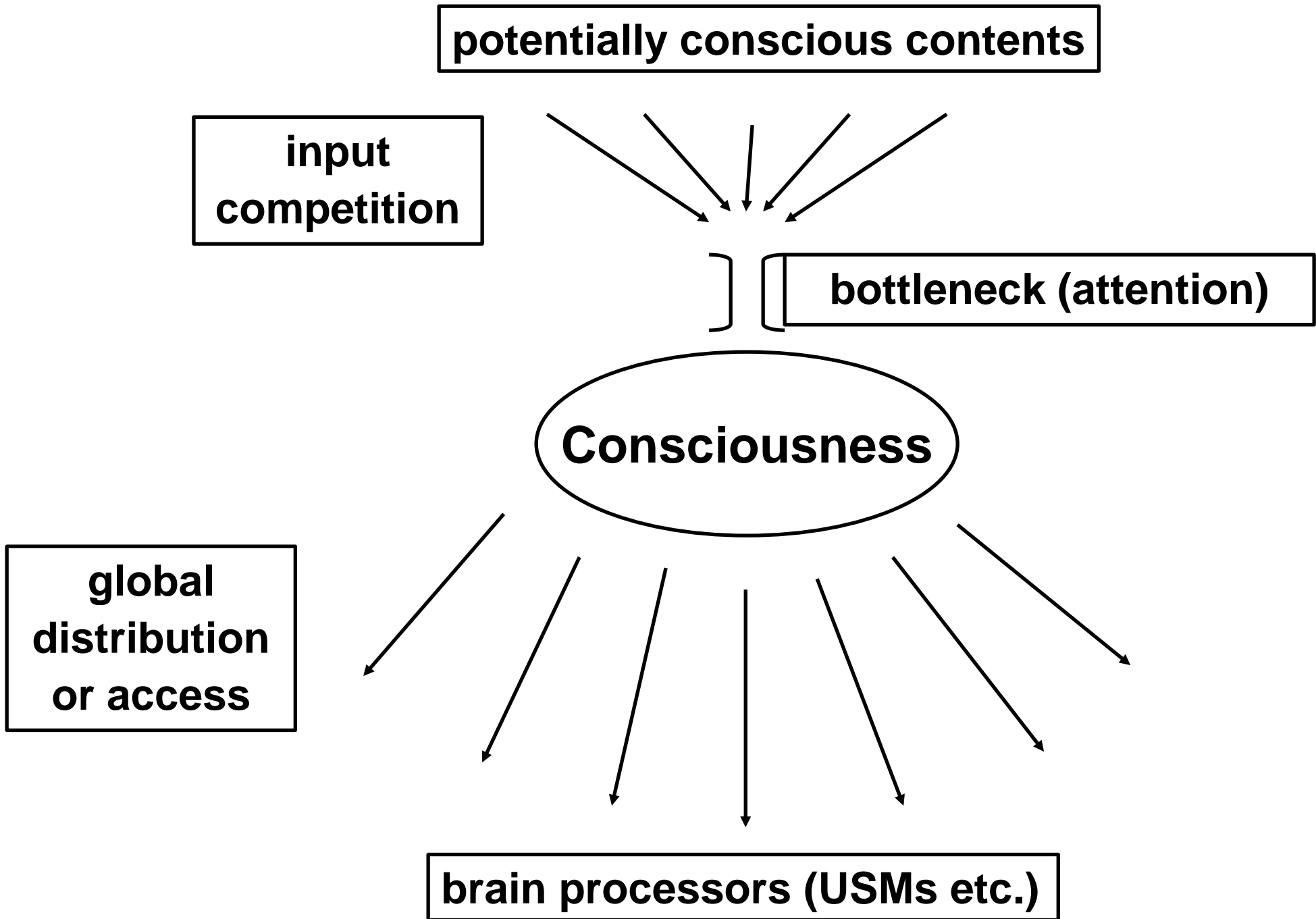
**input
competition**

bottleneck (attention)

Consciousness

**global
distribution
or access**

brain processors (USMs etc.)



GW as a theater

- **This is the basic idea of the global workspace: input competition and global distribution of information in consciousness**
- **But the complete GW model has more features, which Baars has summarized into a neat and powerful metaphor: the theater metaphor of consciousness**

Context operators behind the scenes

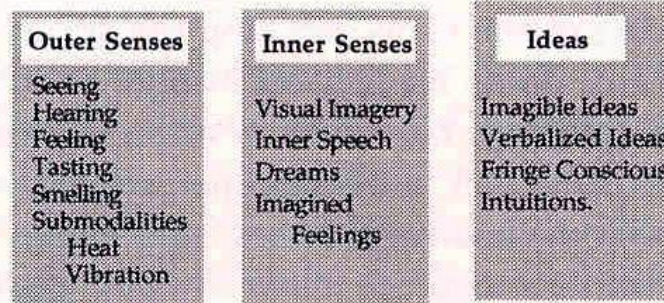
Director

Spotlight
Controller

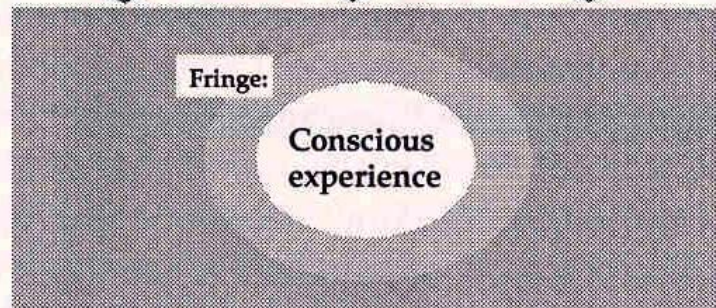
Local Contexts

Competing for access to consciousness:

*the
players ...*



*... the spotlight
of attention
shining on the
stage
of working
memory ...*



Working memory receives conscious input, controls inner speech, uses imagery for spatial tasks, all under voluntary control.

the unconscious audience...

Memory systems:

Lexicon
Semantic networks
Autobiographical
& declarative memory
Beliefs, knowledge
of the world, of
oneself and others.

Interpreting conscious contents:

Recognizing objects, faces, speech,
events. Syntactic analysis. Spatial
relationships. Social inferences.

Automatisms:

Skill memory.
Details of language,
action control, reading,
thinking, and
thousands more ...

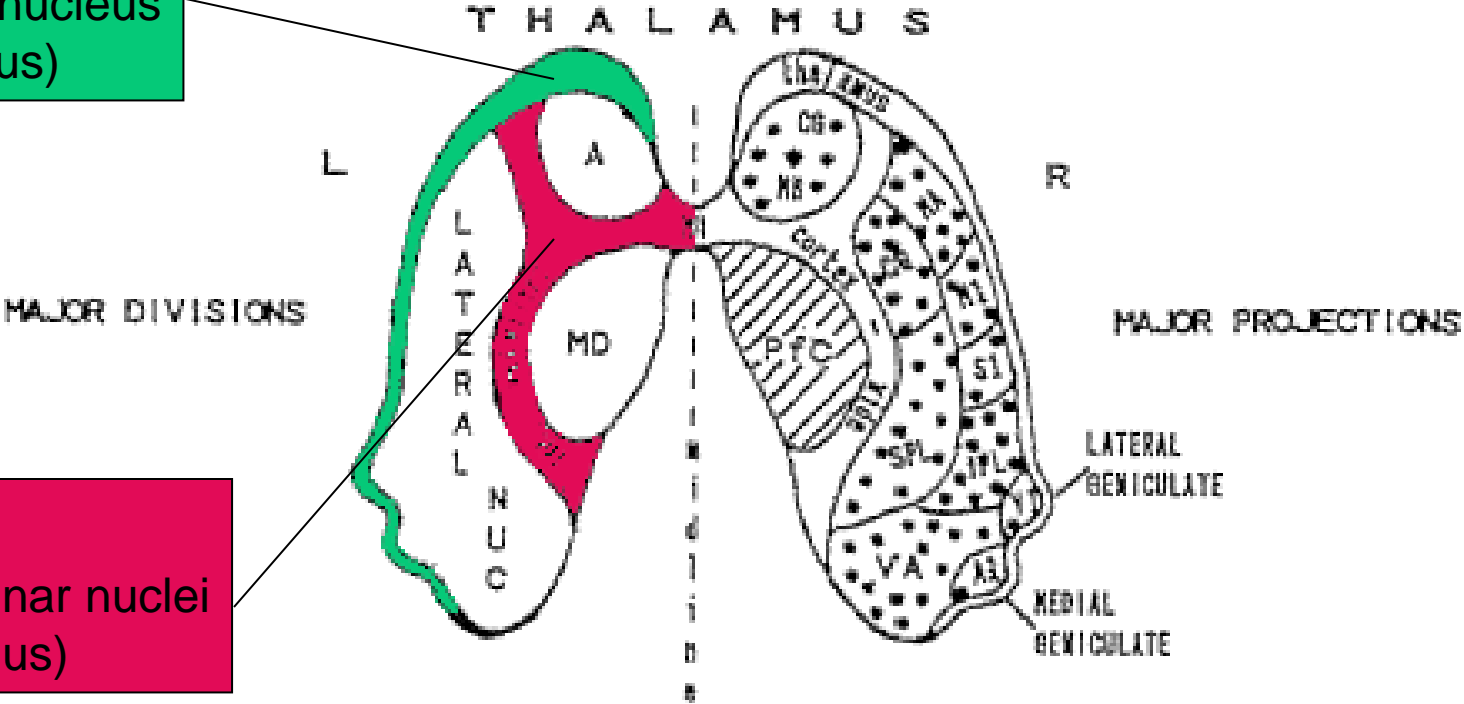
Neural global workspace (NGW)

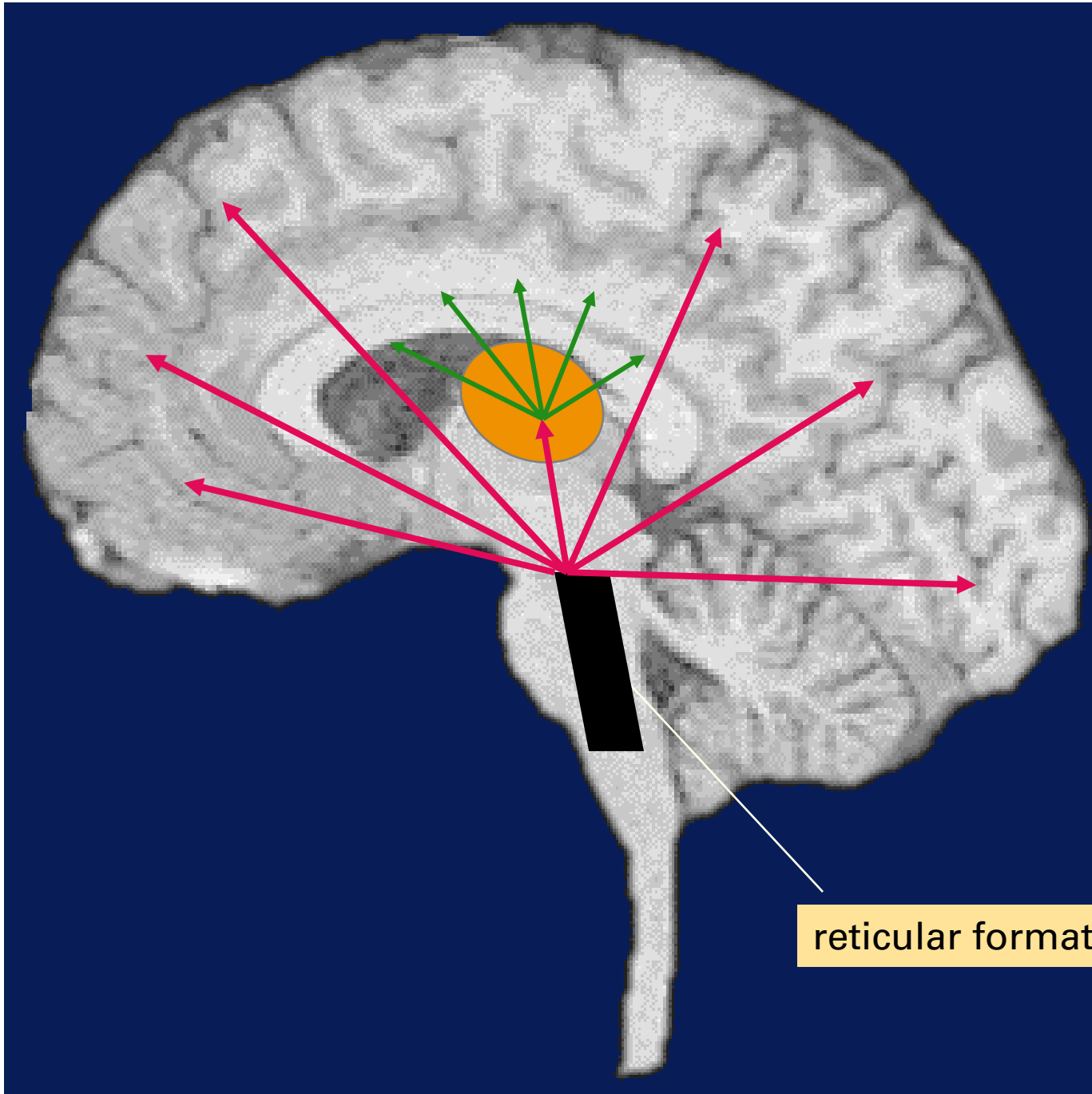
- We're looking for brain systems that could implement a global workspace architecture with input competition for access to consciousness, selection of a content for consciousness ("attentional bottleneck") and global broadcasting / distribution of this content
- These are:
 - brainstem reticular formation (RF)
 - reticular nucleus of thalamus (NRT) and intralaminar nuclei of thalamus (ILN)

Horizontal cut through the brain, view from above

NRT
(reticular nucleus of thalamus)

ILN
(intralaminar nuclei of thalamus)





reticular formation (RF)

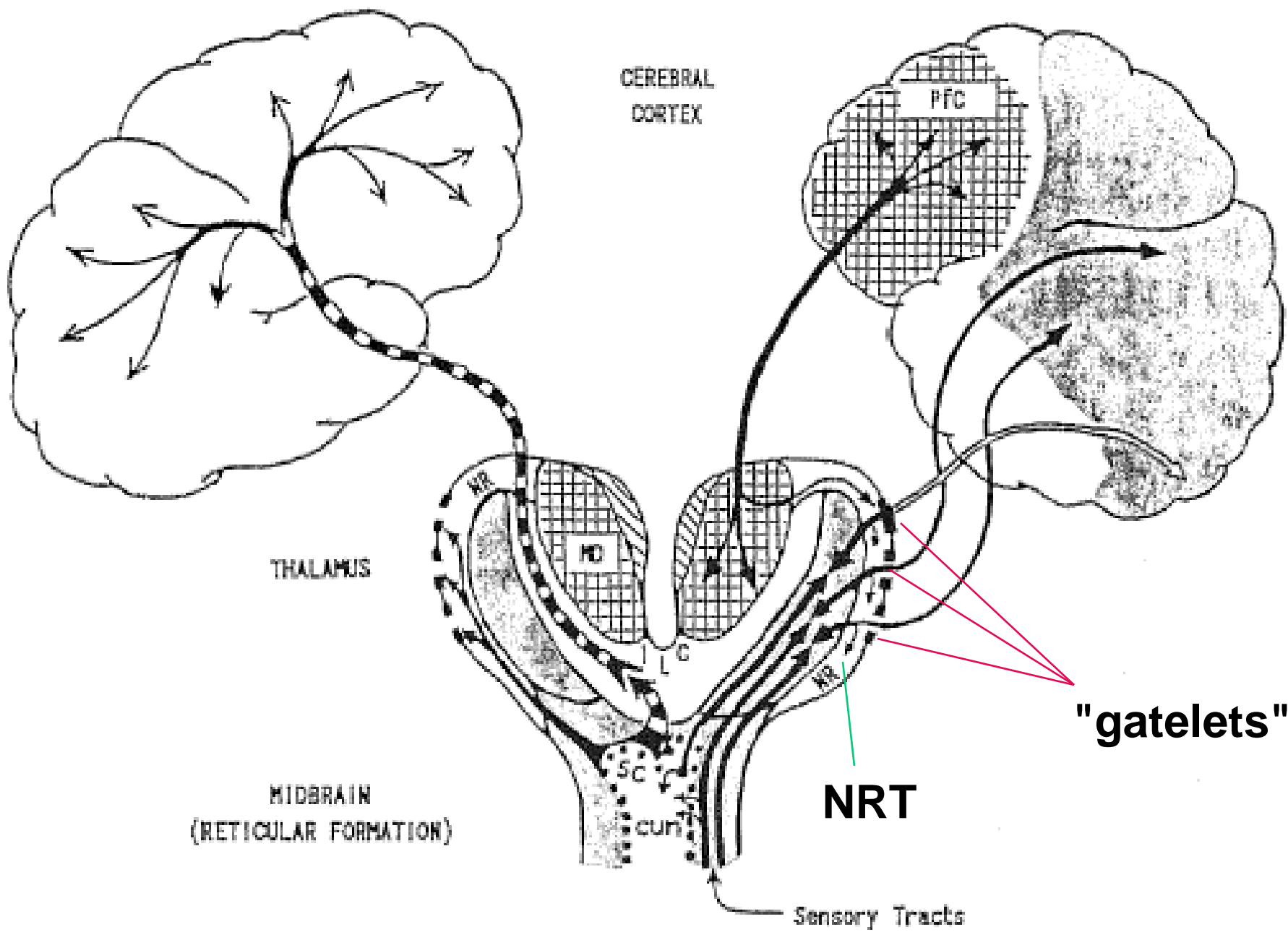
NRT

(reticular nucleus of thalamus)

- **The NRT is like a sheet covering the lateral surface of the thalamus**
- **It consists only of inhibitory neurons**
- **It is extensively connected with the specific (incl. sensory) nuclei of the thalamus → modulation of specific nuclei**
- **Nearly all information from the thalamus to the cortex passes through the NRT → the NRT is in an ideal strategic position to gate, control, select the information that flows to the cortex**
- **The NRT is therefore said to consist of "gatelets", i.e. an array of gating circuits**
- **The NRT itself sends no projections to the cortex, but it receives collateral projections from nearly all of the cortex**
- **The NRT is also interconnected with**
 - **ILN**
 - **midbrain/brainstem reticular formation**

Brainstem reticular formation

- **RF = diffuse, global activation system**
- **"Diffuse", because the RF has widespread, unspecific projections to the cortex**
- **Stimulation of RF activates cortex → arousal**
- **Shut-down of the RF leads to coma**
- **"Reticular" means "network-like", because RF neurons form a densely interconnected network**
- **The RF receives input from all major sensory and motor system of the brain, incl. extensive collaterals from sensory pathways on their way to the thalamus**



CEREBRAL
CORTEX

PFC

THALAMUS

MIDBRAIN
(RETICULAR FORMATION)

NRT

Sensory Tracts

"gatelets"

NRT

(reticular nucleus of thalamus)

- **The NRT shows input competition: it selects from among a number of inputs (e.g. visual, auditory, somatic) one for access to the cortex, by opening the corresponding gatelet, and by shutting down the other gatelets**
- **Thinking back to the theater metaphor of the global workspace, the NRT could therefore be the mechanism implementing the spotlight of attention that selectively highlights one particular content of consciousness**
- **But what does the global broadcasting of this content?**

Thalamus and Cortex

- **All or nearly all connections from thalamus to cortex are reciprocal**
- **In fact, the cortex sends back 10 times as many projections to the thalamus as it receives from it!**
- **The thalamus provides about 90% of the extrinsic input to the cortex!**
- **However, only about 10% of projections ending in the cortex are extrinsic, 90% of them are intracortical connections!**

Thalamus and Cortex

- **The strong reciprocal connectivity between thalamus and cortex suggests the presence of thalamocortical feedback loops**
- **Baars suggests that what is selected by the NRT are such loops that are established between specific nuclei of the thalamus and their cortical projection area**
- **The NRT will support the establishment of one such loop, simultaneously suppressing the establishment of other competing loops**

Global broadcasting

- **According to Baars, global broadcasting of content could be achieved through**
 - **massive axonal projections from posterior to anterior cortex and between the left and right hemispheres of the brain**
 - **the so-called "tangential intracortical network" (TIN) in the upper layers of cortex, consisting mainly of axon collaterals and dendritic ramifications of pyramidal cells**
 - **perhaps also by diffuse projections to the cortex from the unspecific thalamus (ILN)**

Neural global workspace

- **The big picture**
 1. **Various streams of input arrive at the specific nuclei of thalamus**
 2. **The NRT selects one input for establishment of a thalamocortical feedback loop with the corresponding cortical projection area**
 3. **The NRT itself is controlled by input from attentional systems, e.g. executive systems in the frontal cortex and anterior cingulate**
 4. **The selected input is globally broadcast via intracortical connections (e.g TIN), and maybe via the diffuse, nonspecific thalamocortical projection system of the ILN**
 5. **Global broadcasting is associated with consciousness**
 6. **The recipients of the global message are various distributed systems in the brain: USMs, memory systems, motivational, emotional systems...**
 7. **The reticular formation controls the overall activity level of the system, it is like a power switch that can turn on or off the workspace. Activating the RF leads to inhibition of NRT and thus opening of the gates**