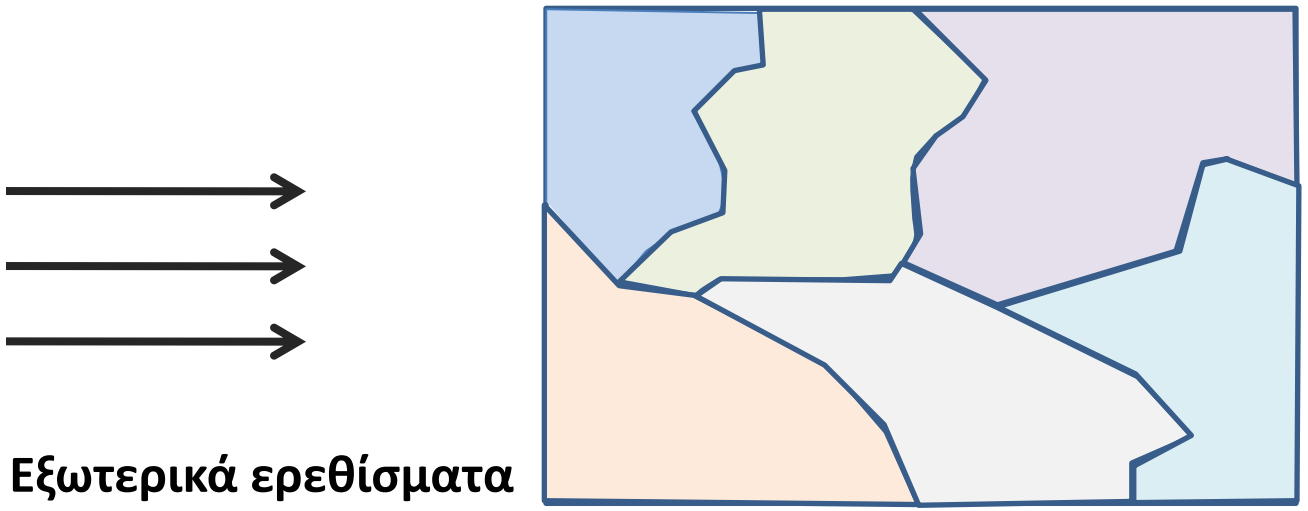
Cognitive Modeling
(Γνωστική μοντελοποίηση)

Kleanthis Neokleous, PhD

Ο εγκέφαλος σαν ένα πληροφορικό σύστημα.

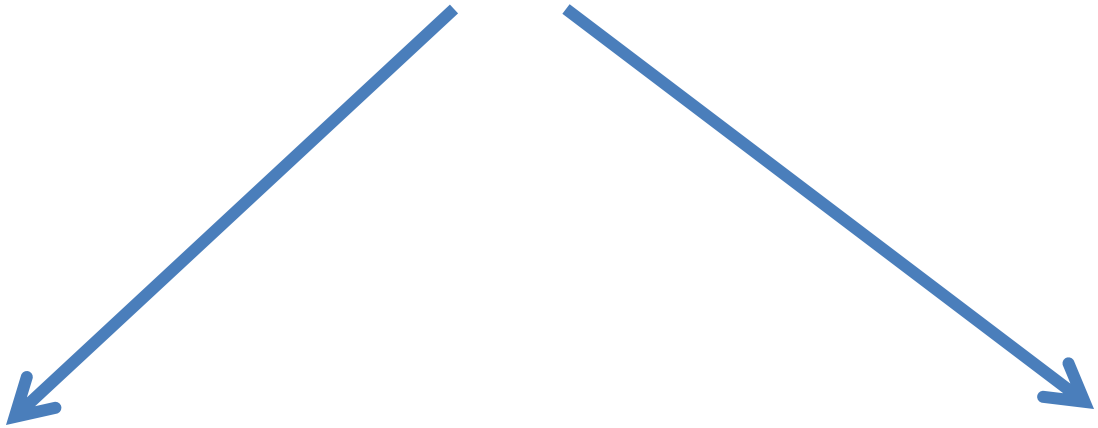


Εξωτερικά ερεθίσματα (αισθητήρια όργανα)

Ανταπόκριση (έξοδος του συστήματος)

Πώς προσπαθούμε να μελετήσουμε τον εγκέφαλο?

Ο εγκέφαλος σαν ένα πληροφορικό σύστημα.



Προσπαθούμε να «αντιγράψουμε» τη λειτουργία του εγκεφάλου με σκοπό να την εφαρμόσουμε σε αλγόριθμους και τεχνικές υπολογιστικής νοημοσύνης.

Δημιουργώντας υπολογιστικά μοντέλα γνωστικών λειτουργιών με σκοπό να αυξήσουμε τις γνώσεις μας για τις συγκεκριμένες λειτουργίες.

Γνωστικά μοντέλα – ένα παράδειγμα.

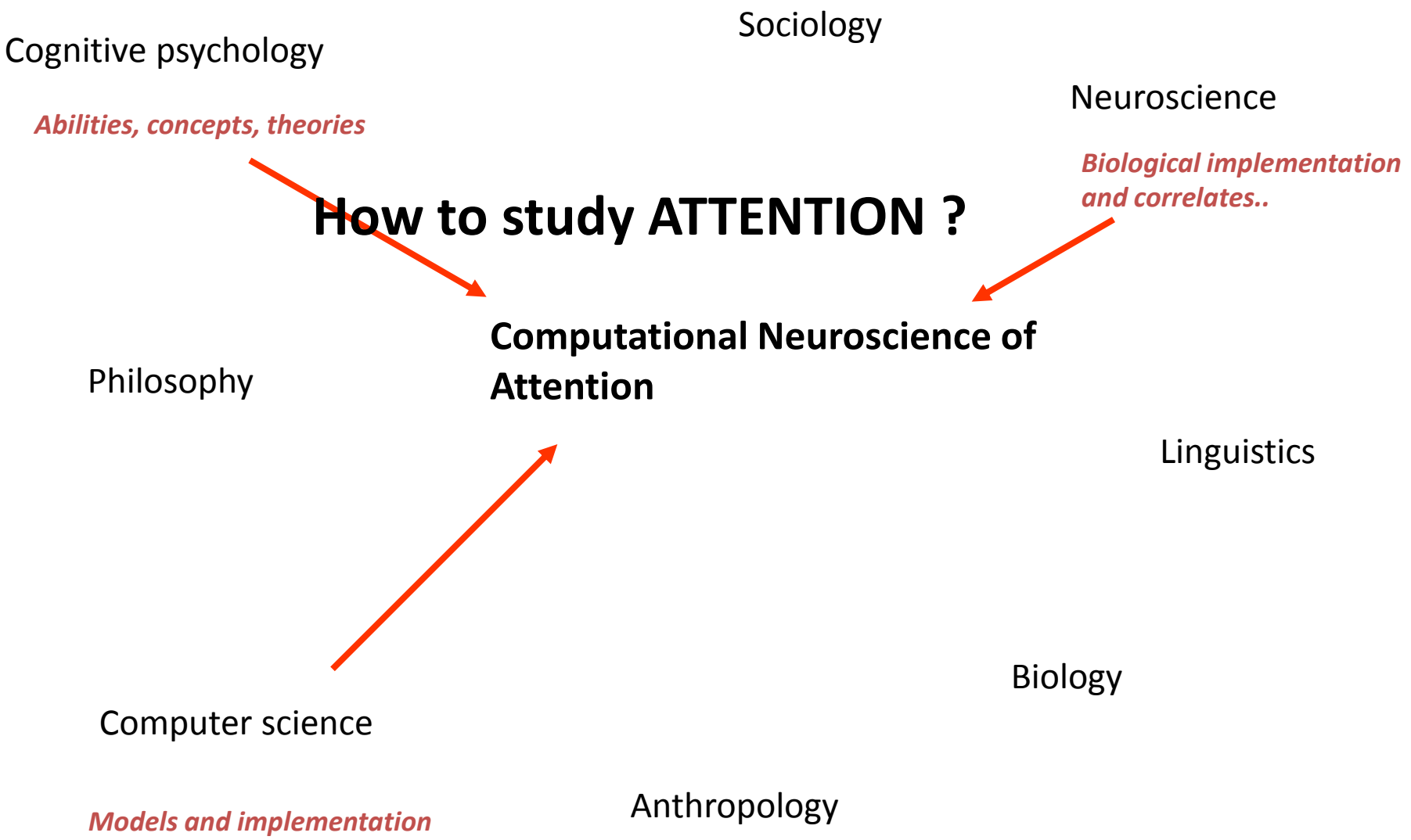
Υπολογιστικό μοντέλο **οπτικής επιλεκτικής προσοχής**

Επιλεκτική προσοχή: Η δυνατότητα ενός ατόμου στο να εστιάσει την προσοχή του σε ένα συγκεκριμένο ερέθισμα ενώ παράλληλα «απορρίπτει» ή «φιλτράρει» όλα τα άλλα που παρεμβάλουν.

For example : The Cocktail party..

Computational neuroscience: *The study of the nature of intelligence.*

Cognitive science is an interdisciplinary field with contributors from various fields



Οπτική Επιλεκτική Προσοχή

Εξωγενής προσοχή

Όταν έντονα χαρακτηριστικά σε μια οπτική σκηνή «κερδίζουν» την προσοχή

Ενδογενής προσοχή

Όταν πληροφορίες για συγκεκριμένους στόχους από τη λειτουργική μνήμη καθοδηγούν την προσοχή.

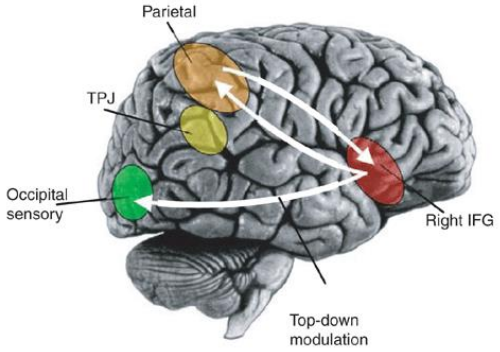

GALERIA JARDIN
NOSSA
NOSSA
VICTO
Los pequeños precios de McDonald's
ROMUSICA
Mald's

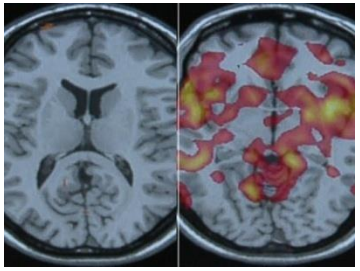
The Garden of Earthly Delights **by Hieronymous Bosch.**

Neuroscience

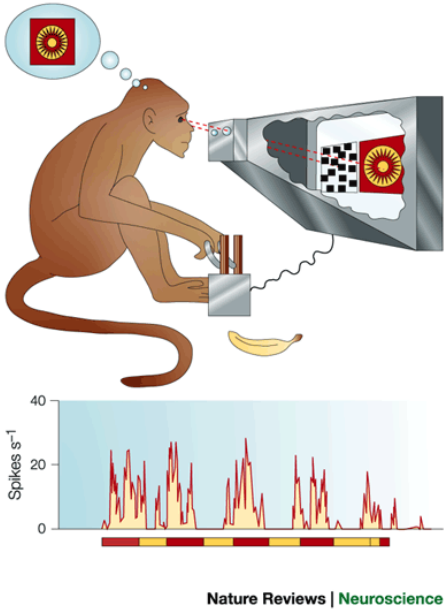
Neuroimaging Techniques
MEGs, fMRI…

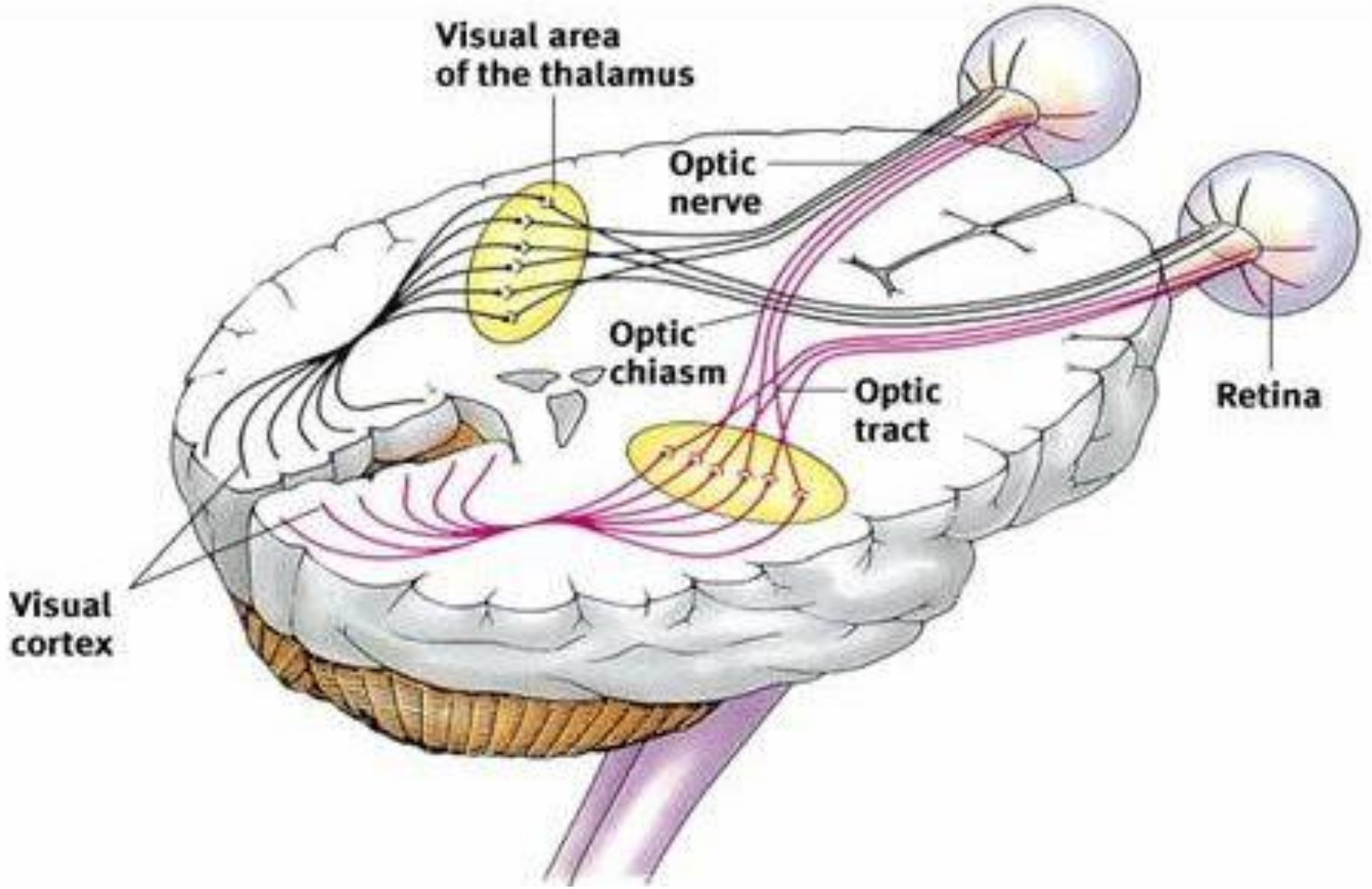
Visual cortex, PFC, anterior cingulate cortex...



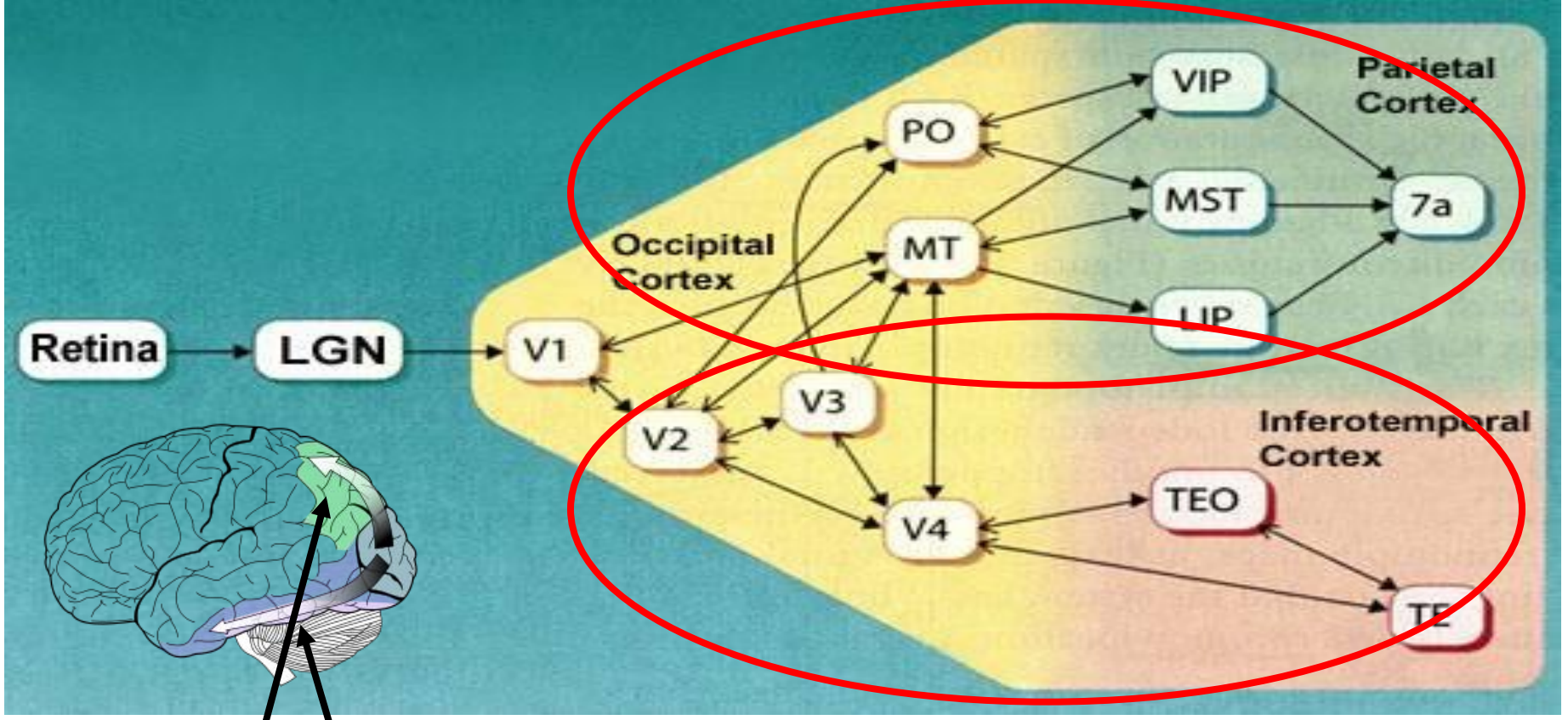


Single Cell Recordings.





Signals produced by the **neural cells in the retina** are propagated then into the brain through the **optic nerve** and reach a major relay station, the **LGN (lateral geniculate nucleus)**



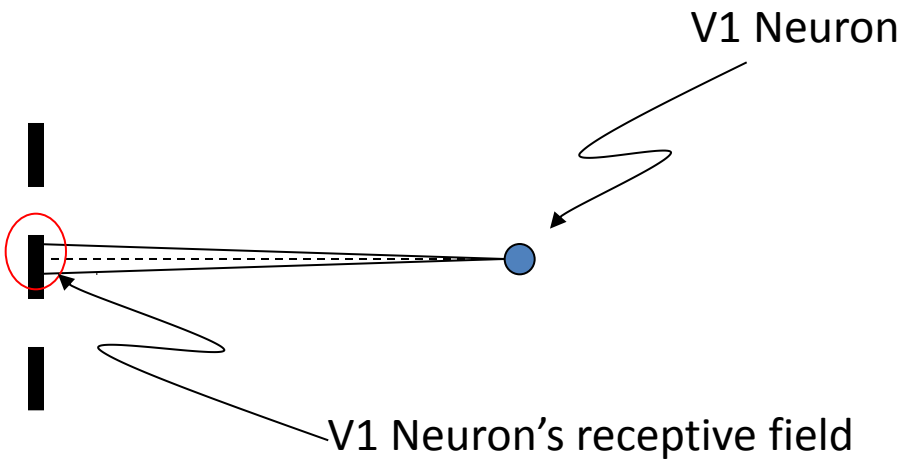
Ventral visual stream seems to be involved in forming conscious representations of the identity of objects –**What pathway**…

The dorsal stream, sometimes called the "**Where Pathway" or "How Pathway**", is associated with motion, representation of object locations, and control of the eyes and arms…

Receptive Field: "an area in which stimulation leads to response of a particular sensory neuron"

For V1 neurons, the receptive field is small, in the range of approximately 1 degrees of diameter, measured as a visual angle in the center of vision.

This area is very small to cover most complete recognizable visual objects, but only a portion of it.

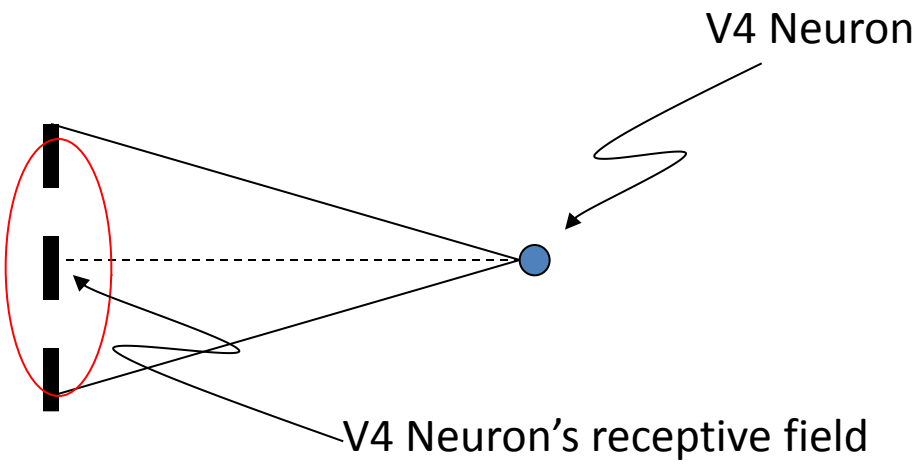


Rolls E.T. (2004) Invariant Object and Face recognition. The Visual Neuroscience Eds. Chalupa LM. and Werner JS. p. 1165-1178.MIT press.

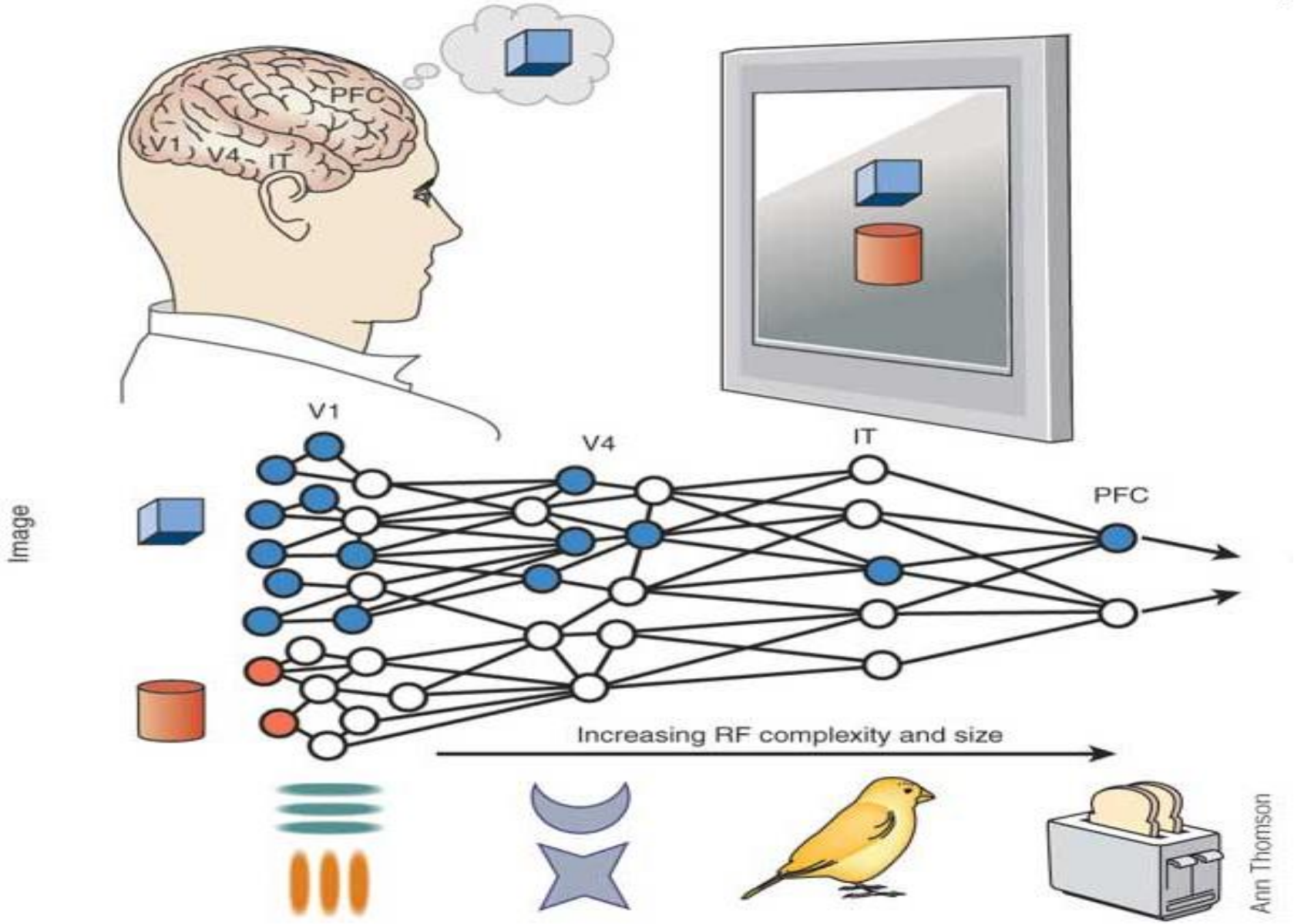
Receptive Field: "an area in which stimulation leads to response of a particular sensory neuron"

In area V4 the neural receptive field becomes larger, in the range of 10 degrees in visual angle diameter, and 20-50 degrees in inferotemporal cortex (IT).

That is in the **IT** it is possible that a single neuron might signal the recognition of a small visual object (Rolls 2004).

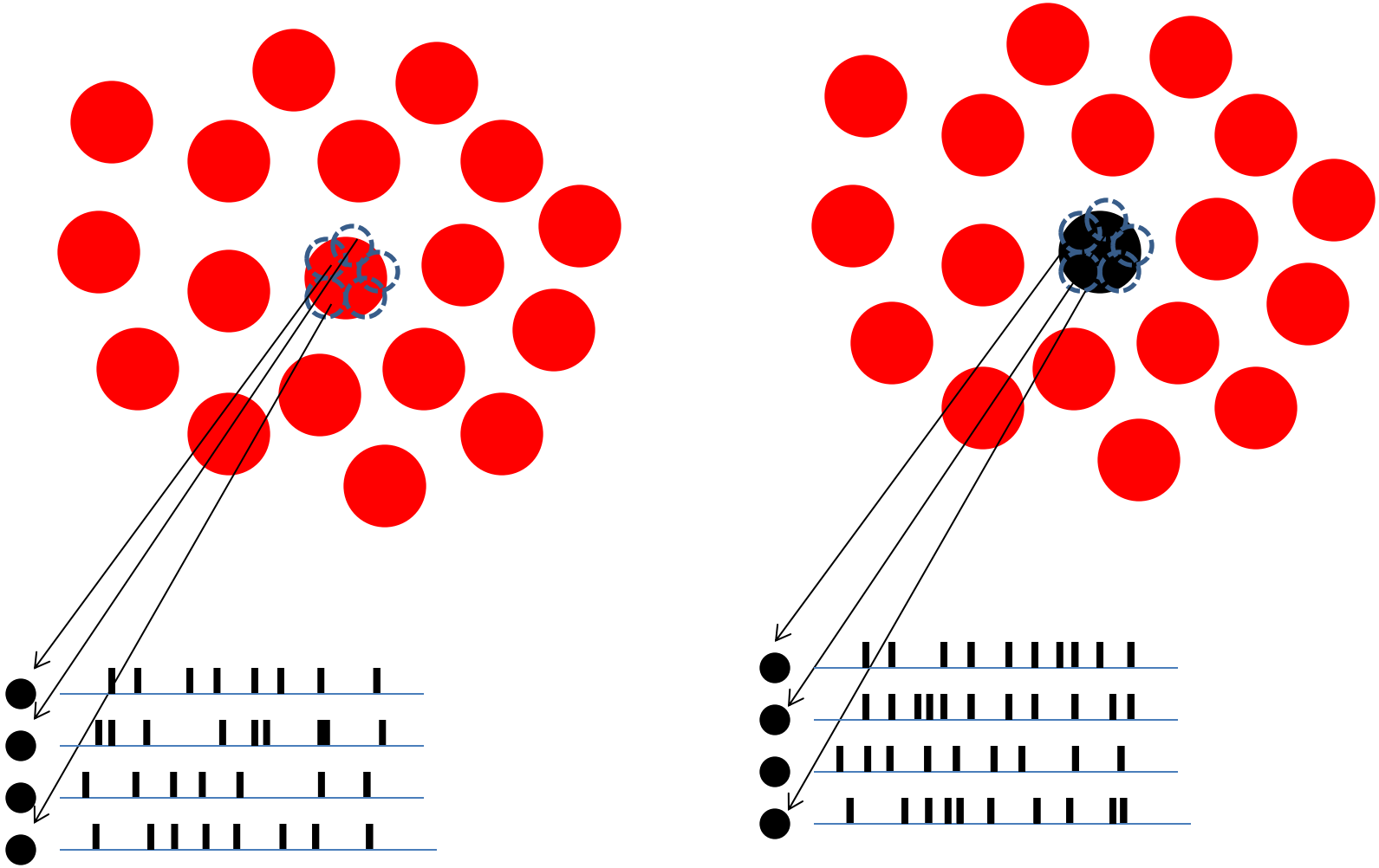


Rolls E.T. (2004) Invariant Object and Face recognition. The Visual Neuroscience Eds. Chalupa LM. and Werner JS. p. 1165-1178.MIT press.



Steven Yantis 2005, **How visual salience wins the battle for awareness** *Nature Neuroscience* **8**, 975 - 977

Επεξεργασία διαφόρων ερεθισμάτων…

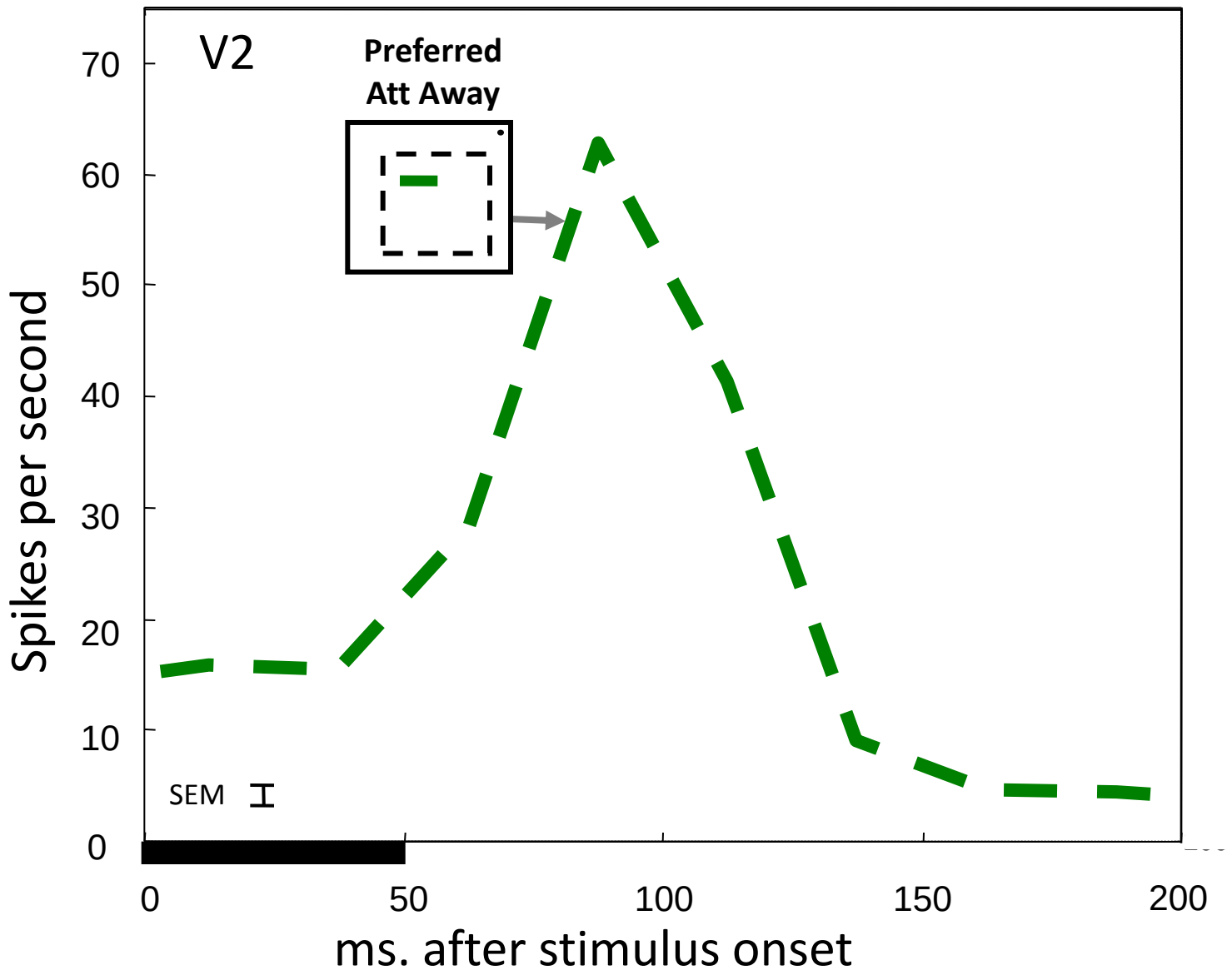


Ψάξτε για τον μαύρο κύκλο..

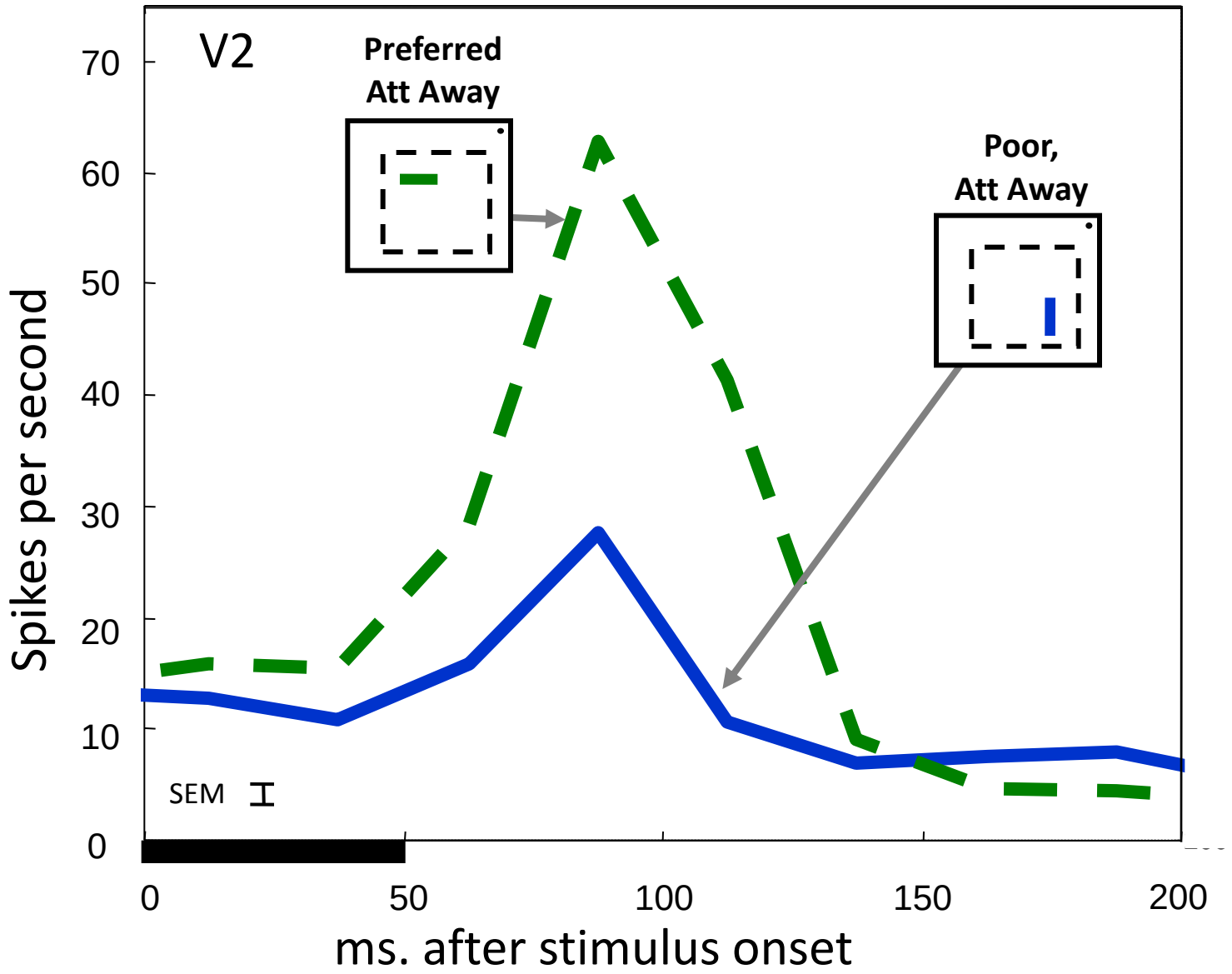
In general, attention in the neuronal level can be seen as **a competitive process**.

Whenever two or more stimuli are represented in the same receptive field of a single cell, **competition can result**.

This competition is translated mainly by the mechanisms of selection by attention and can be influenced by either **bottom-up saliency cues or top- down volitional cues.**



Reynolds, Chelazzi and Desimone, 1999, J. Neurosci.



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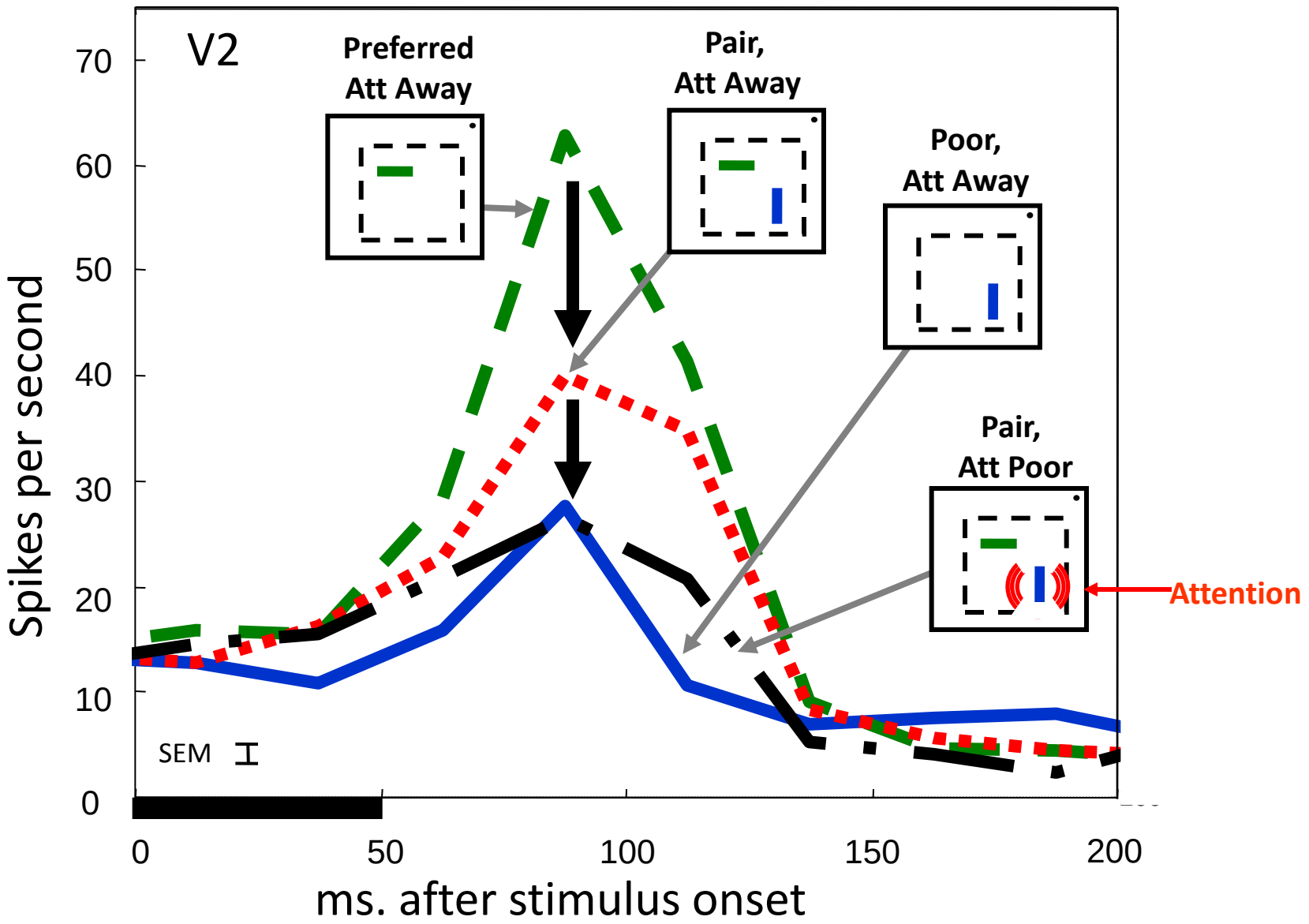
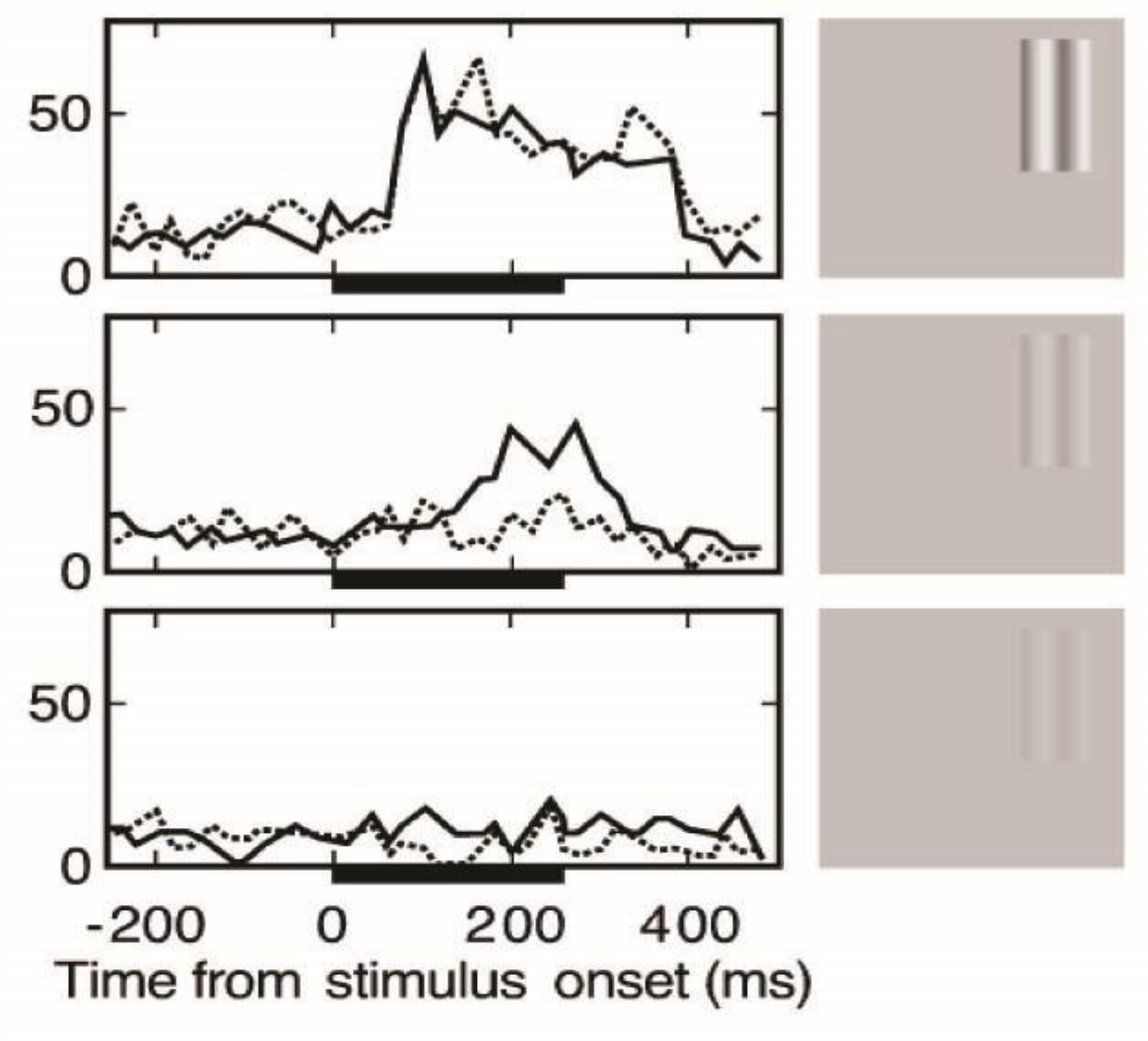


Reynolds, Chelazzi and Desimone, 1999, J. Neurosci.

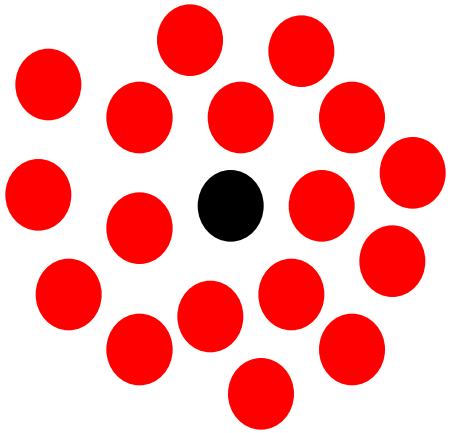


Responses of an example area **V4 neuron** as a function of attention and stimulus contrast.

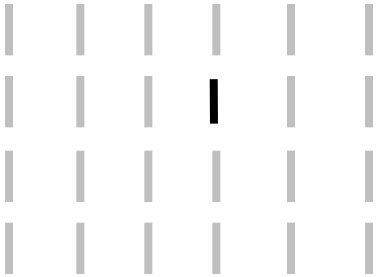
John H. Reynolds & Leonardo Chelazzi, ***Annual Review of Neuroscience, 2004, 27: 611-647***

Bottom-up attention

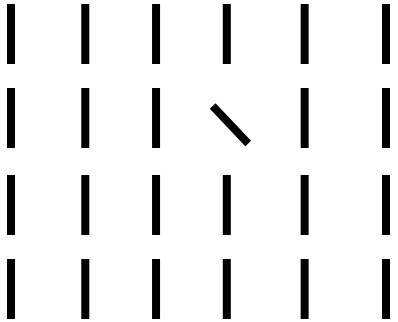
Colour



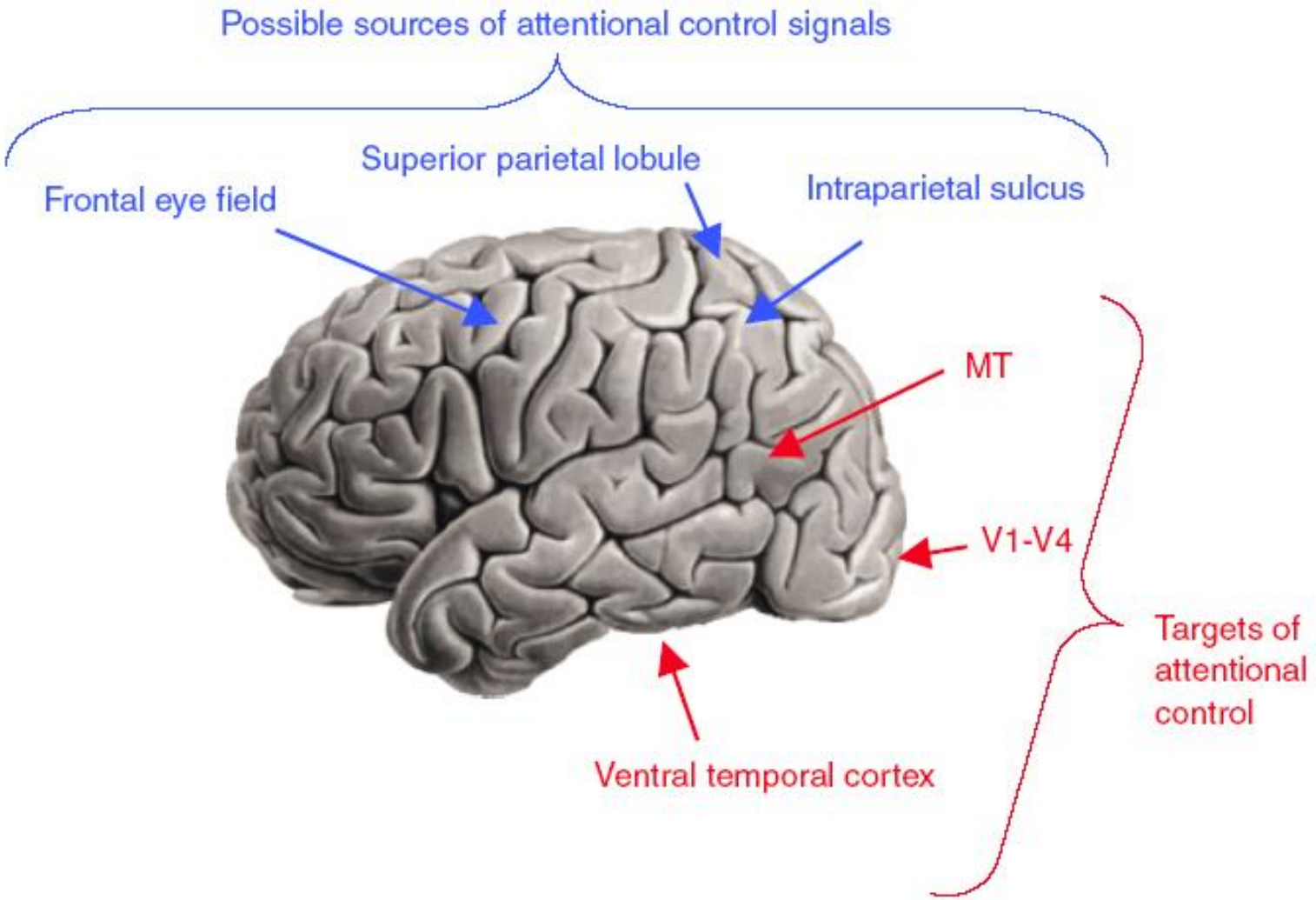
Intensity



Orientation



Top-Down attention



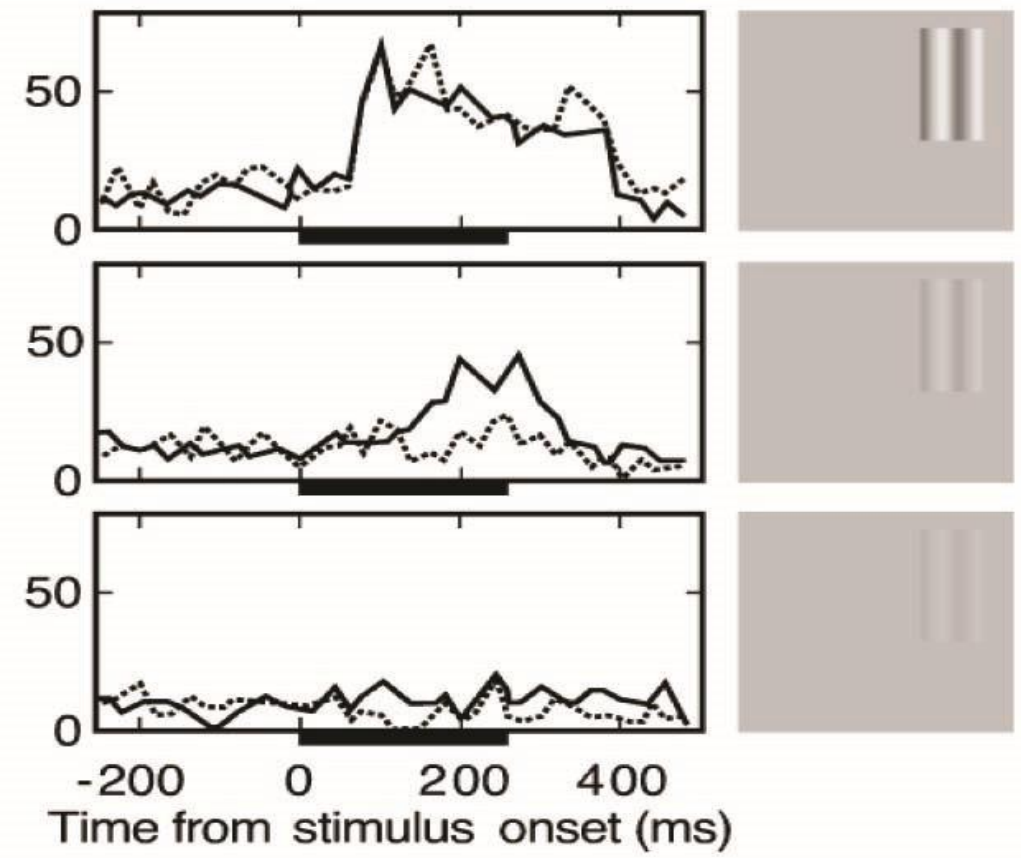
Eric I. Knudsen, **Fundamental Components of Attention,** *Annu. Rev. Neurosci. 2007*

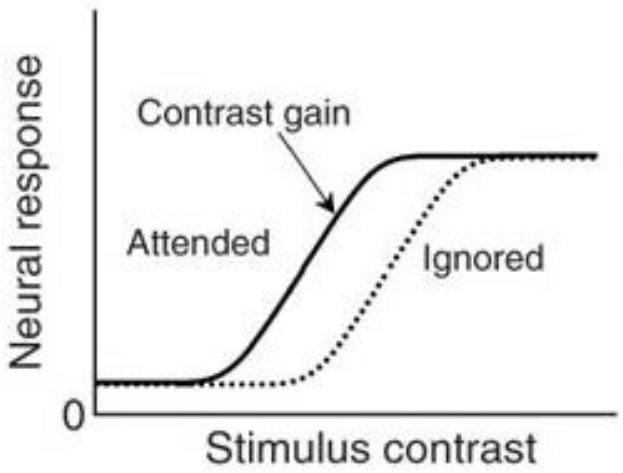
Rate-based mechanism of selection

The simplest selection process is a rate-based mechanism.

-Responses of neurons in early processing stages that convey information to be selected are made more prominent by raising their firing rates.

-Responses of neurons that convey information to be ignored are made less prominent by suppressing or decreasing their firing rates.





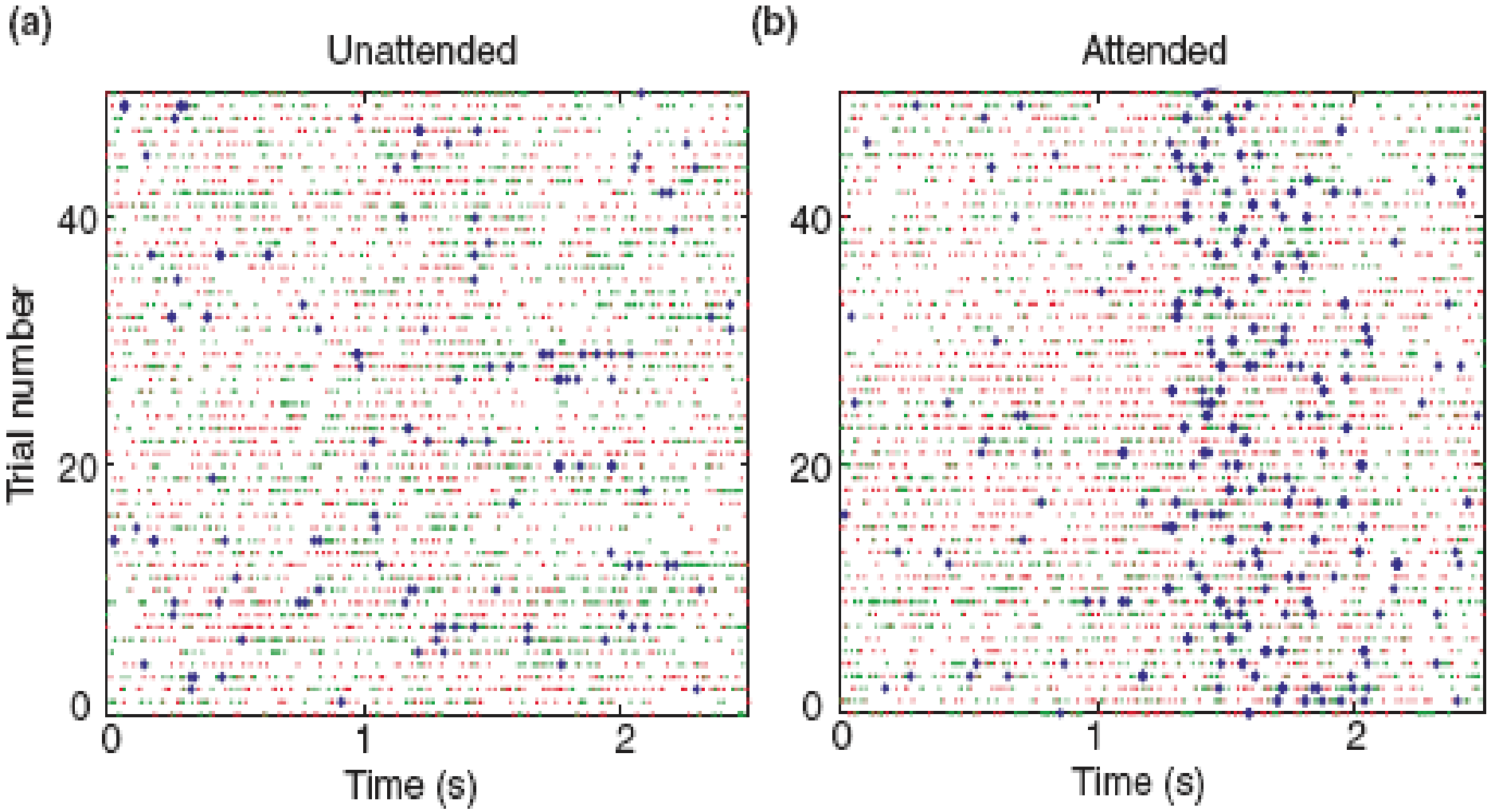
Yee Joon Kim et al., **Attention induces synchronization-based response gain in steady-state visual evoked potentials**
Nature Neuroscience

Synchronization as a neuronal mechanism of selection.

The theoretical basis for synchrony as a mechanism for attentional selection was originally proposed by Crick and Koch (1990).

Francis Crick (8 June 1916 – 28 July 2004)
The Nobel Prize in Physiology or Medicine 1962

It was suggested that visual selective attention functions in a way that there is a change in the temporal structure of the neural spike trains representing the source that is to be selected

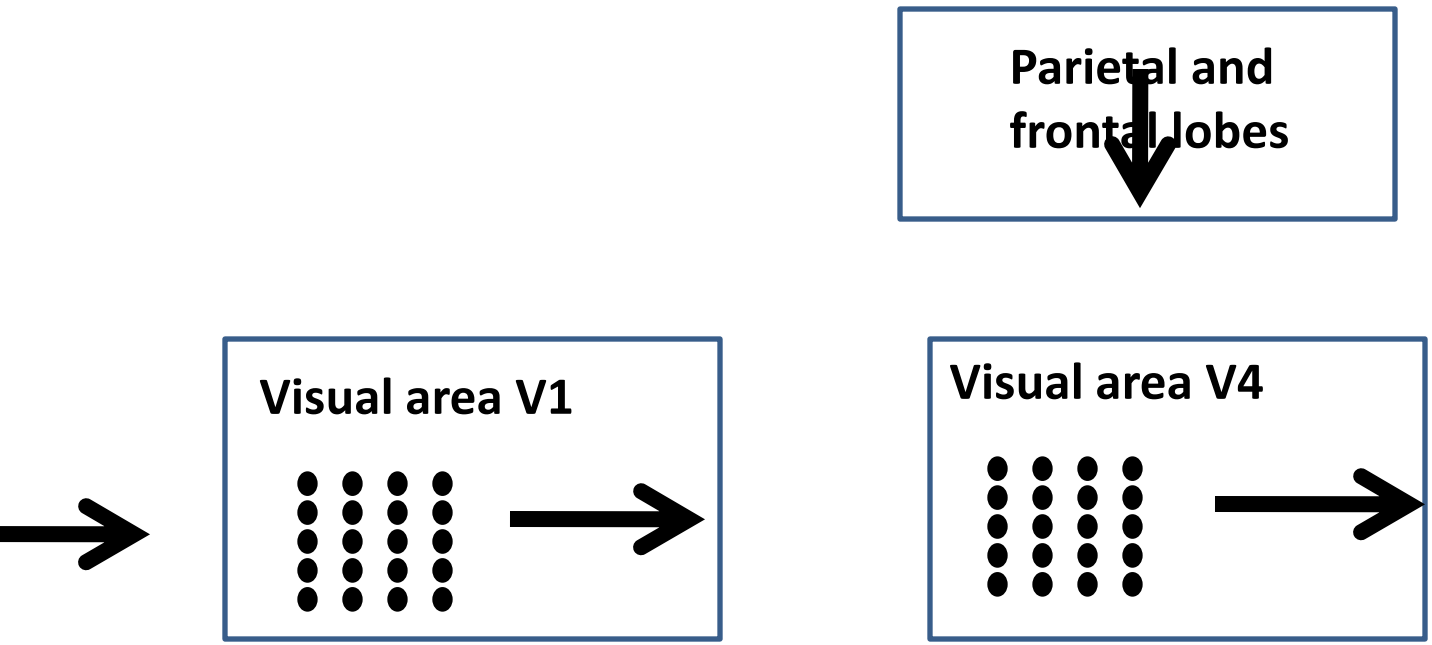


Niebur E., Hsiao S.S., Johnson K.O., (2002) "Synchrony: a neuronal mechanism for attentional selection?" ***Cur.Op. in Neurobio.*****, 12:190–194**

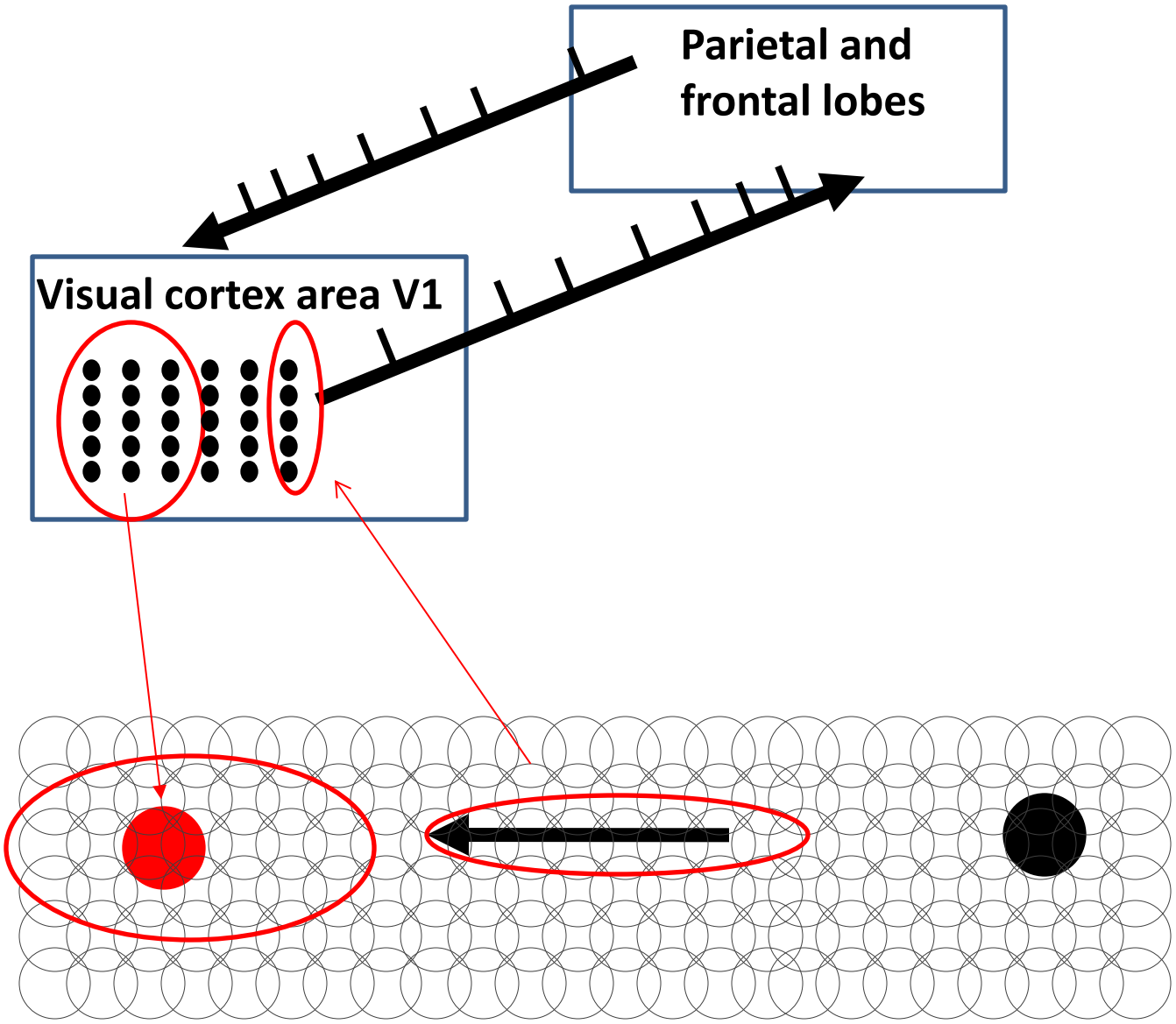
Semantic Top-Down attention

Neural activity is known to be affected by **semantic top-down attention mostly in area V4,** the intermediate stage of visual object-processing pathway in the brain (Moran & Desimone, 1985; Connor et al., 1997; Reynolds & Desimone, 2003).

- **Increase of firing rate…**
- **Increase of synchronization in the neural activity…**



Spatial Top-Down attention



Attention - Cognitive Psychology

Behavioral Experiments!

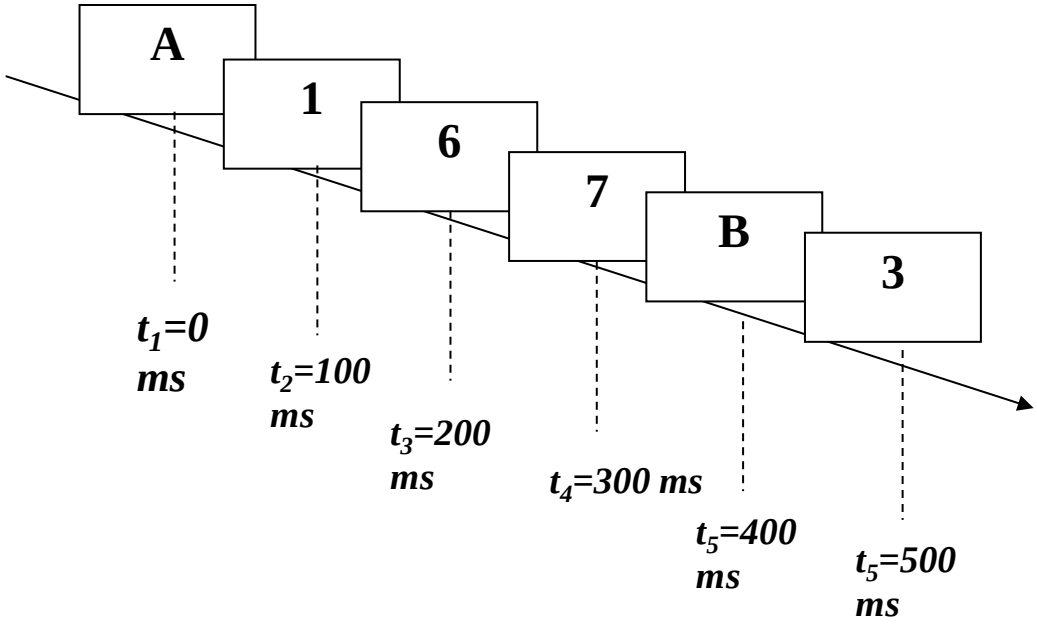
Important observations mainly studying accuracy and reaction time.

The Attentional Blink

Raymond, Shapiro and Arnell (1992).

Refers to the refractory period following the identification of a visual target (T1) **within a Rapid Serial Visual Presentation (RSVP)**.

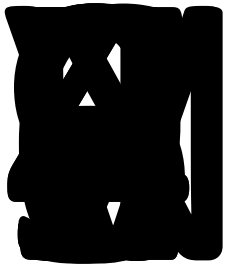
During this period, the human ability of detecting a second visual target (T2) is significantly decreased to approximately **300 to 500 ms.**



Raymond JE, Shapiro KL, Arnell KM (1992). "**Temporary suppression of visual processing in an RSVP task: an attentional blink?".** *J.of exp. psyc. Human perc, and performance*

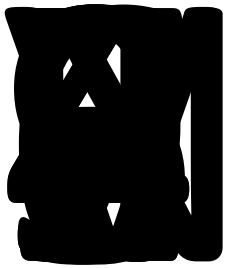
A Demonstration

T2 at Lag 7



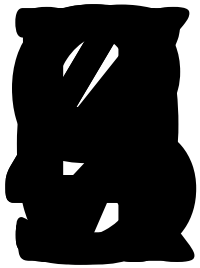
A Demonstration

T2 at Lag 7 – normal speed



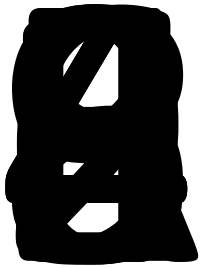
A Demonstration

T2 at Lag 3

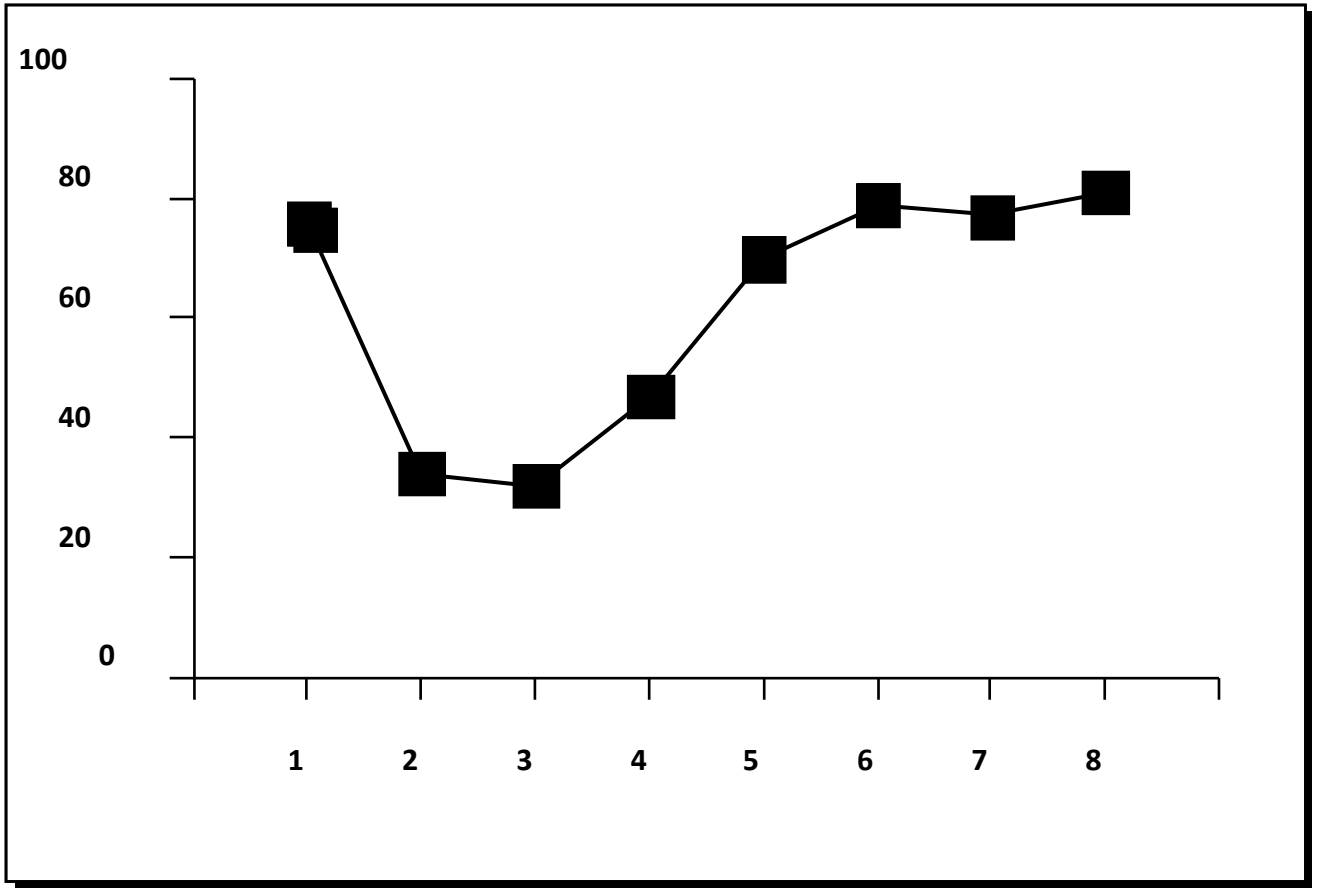


A Demonstration

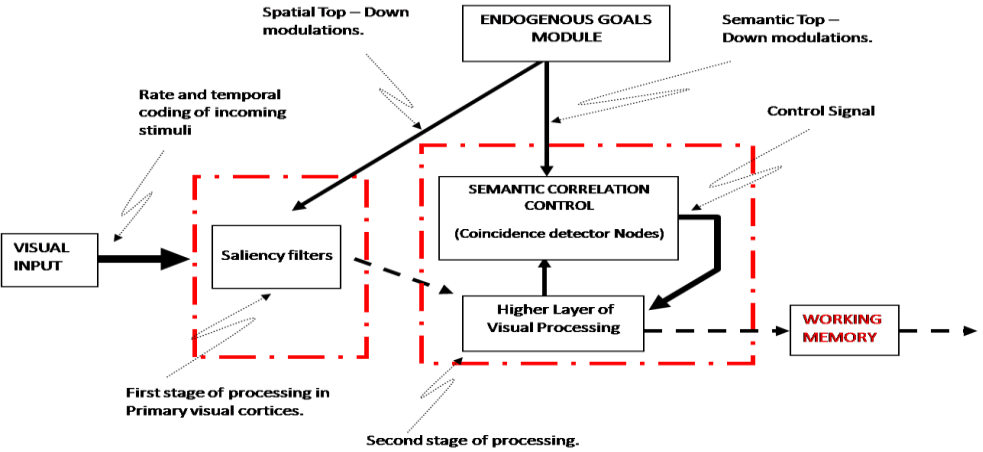
T2 at Lag 1



The Attentional Blink



Computational modeling of **visual selective attention.**



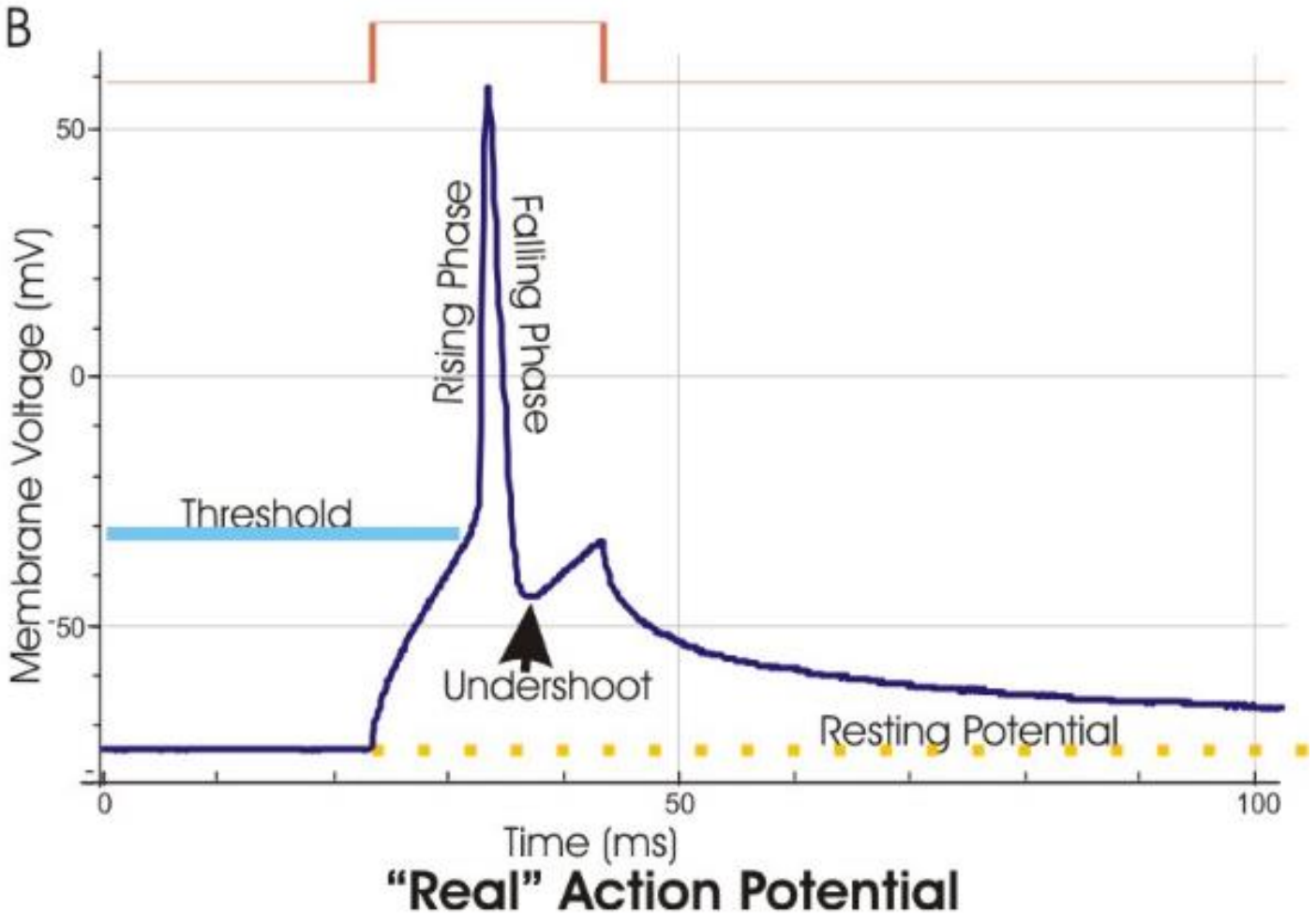
$$\tau_m \frac{dV}{dt} = E_{leak} - V - R_m I$$

$$V(t) = E_{leak} + R_m I + (V(0) - E_{leak} - R_m I)e^{-\left(\frac{t}{\tau}\right)}$$

Through simulations we can gain **new knowledge and information** related with visual selective attention…

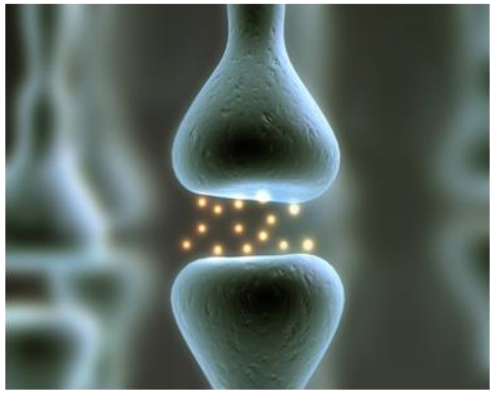
- Evaluate existing theories and contribute in the creation of new..
- Study the interaction and the importance of visual selective attention in various **social, medical** and **computational intelligence** applications…

Μαθηματική ανάλυση του μοντέλου



"Real" Action Potential

Μαθηματική ανάλυση του μοντέλου



Μοντέλα νευρώνων Integrate and fire

$$\tau_m \frac{dV}{dt} = E_{leak} - V(t) + R_m I_s(t)$$

$$I_s(t) = (I_{AMPA}(t) + I_{NMDA}(t)) + (I_{GABA_A}(t) + I_{GABA_B}(t))$$

$$I_s(t) = \left(I_{exc}(t) + I_{inh}(t)\right) = g_{ext}(t)(Es_{ext} - V) + g_{inh}(t)(Es_{inh} - V)$$

$$g_{exc}(t) = \bar{g}_{exc} w_{ext} P_s(t) \text{ and } g_{inh}(t) = \bar{g}_{inh} w_{inh} P_s(t)$$

$$\frac{dP_s}{dt} = -\frac{P_s}{\tau_s} + \sum_k \delta(t - t_k)$$

Διακριτός χρόνος

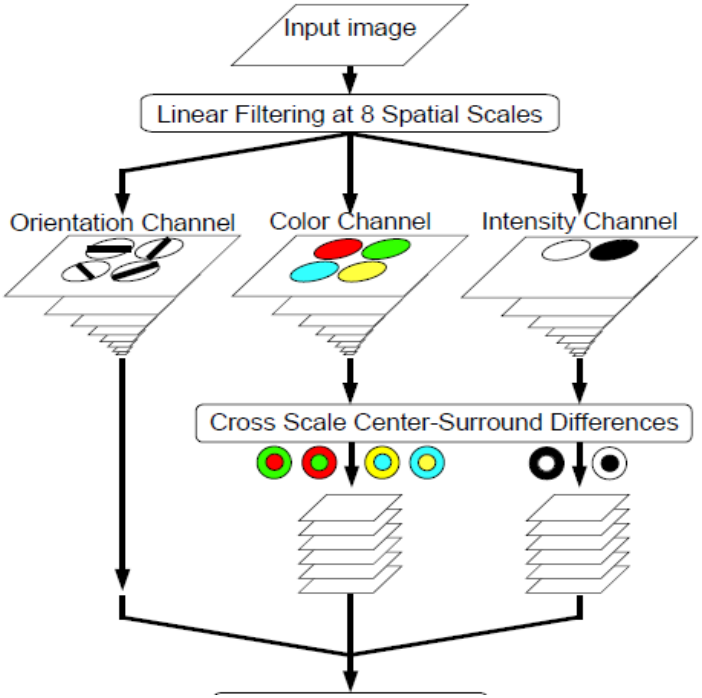
$$V_i(t + \delta t) = (E_{leak} - V)(1 + \frac{dt}{\tau_m}) + \frac{R_m}{\tau_m} I_s(t)\delta t$$

Εξωγενής Προσοχή – υπολογιστική προσέγγιση

Κανάλια αναλύουν διαφορές χρωμάτων, έντασης, και κλίσης στην οπτική εικόνα σε διάφορες χωρικές κλίμακες.

Π.χ.

- 1 κανάλι για διαφορές έντασης
- 2 κανάλια για διαφορές χρωμάτων (κόκκινο – πράσινο και μπλε – κίτρινο).
- 4 κανάλια τα οποία κωδικοποιούν κλίσεις (0^o, 45^o, 90^o, 135^o).



$$\mathbf{I}(c,s) = \left|\mathbf{I}(c)\,\Theta\,\mathbf{I}(s)\right|$$

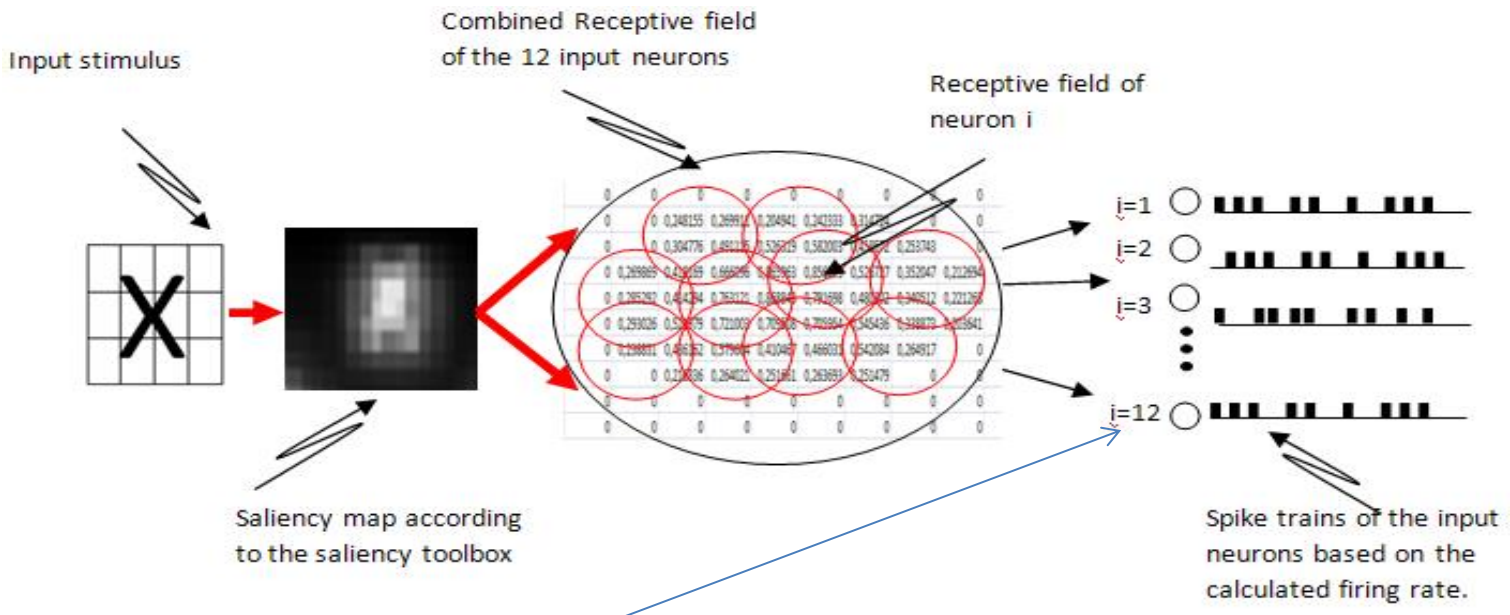
$$\mathbf{RG}(c,s) = \left|\left(\mathbf{R}(c)-\mathbf{G}(c)\right)\Theta\left(\mathbf{G}(s)-\mathbf{R}(s)\right)\right|$$

$$\mathbf{BY}(c,s) = \left|\left(\mathbf{B}(c)-\mathbf{Y}(c)\right)\Theta\left(\mathbf{Y}(s)-\mathbf{B}(s)\right)\right|$$

$$\mathbf{O}(c,s,\theta) = \left|\mathbf{O}(c,\theta)\,\Theta\,\mathbf{O}(s,\theta)\right|$$

*The computation of the specific **feature types** is based on **evidence suggesting their existence in mammalian visual systems** (Leventhal, 1991, Luschow & Nothdurft, 1993; Engel, Zhang & Wandell, 1997,DeValois, Albrecht & Thorell, 1982; Tootell, Hamilton, Silverman & Switkes, 1988).*

Κωδικοποίηση εισερχόμενων ερεθισμάτων



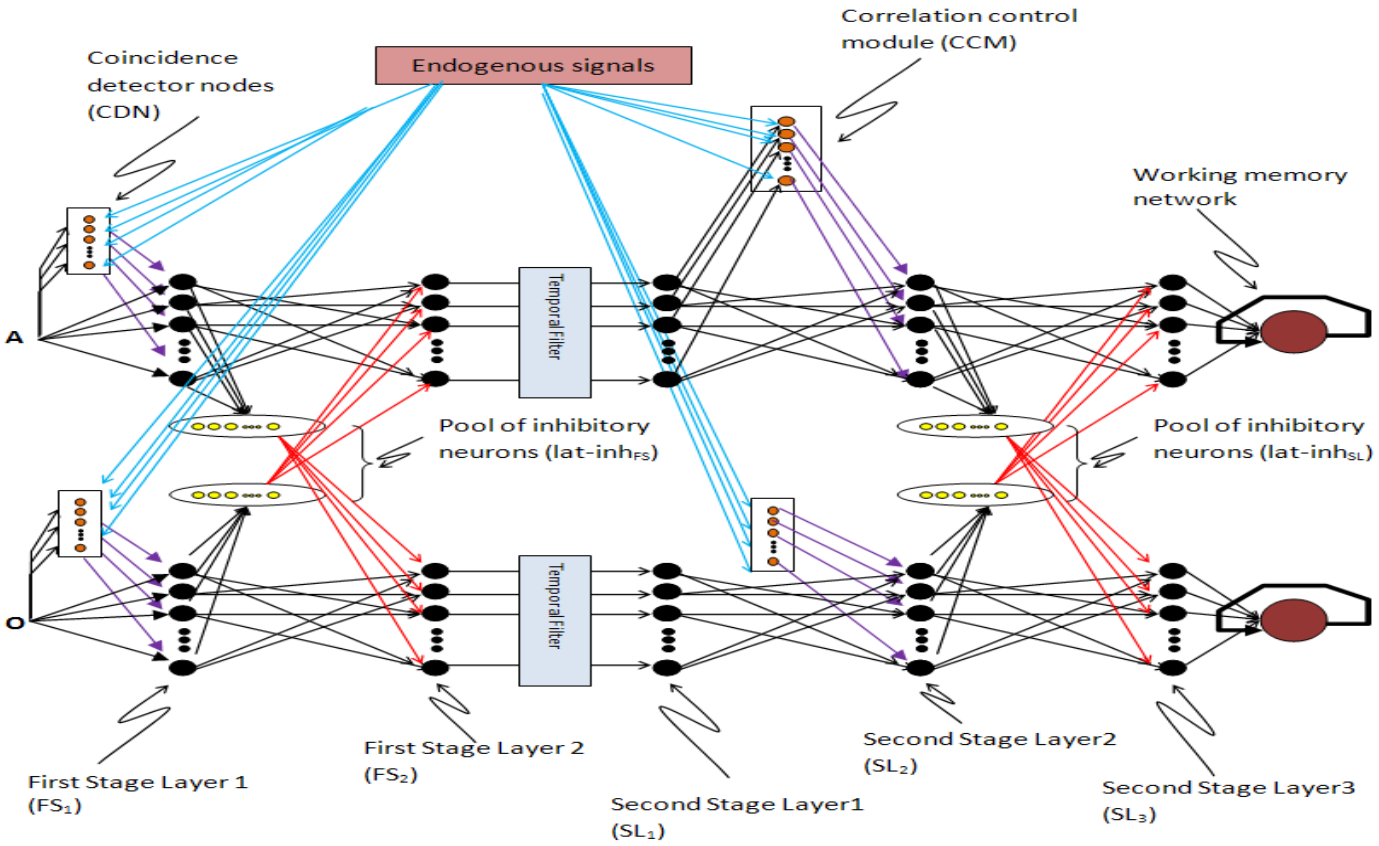
$$FR_{Si} = \alpha\left(Max(Pj)\right) + \beta\left(\sum_{j=1}^{n} Pj\right)$$

FR_{Si} είναι η συχνότητα αντίδρασης των 12 νευρώνων εισόδου που αντιστοιχούν στη θέση του ερεθίσματος Si

Max(Pj) είναι η μέγιστη τιμή από όλα τα pixels που αντιστοιχούν στο ερέθισμα Si

$\sum_{j=1}^{n}$ Pj είναι το συνολικό άθροισμα όλων των τιμών των n pixels Pj που αντιστοιχούν στο ερέθισμα Si.

Αλληλοεπιδράσεις στο νευρωνικό δίκτυο



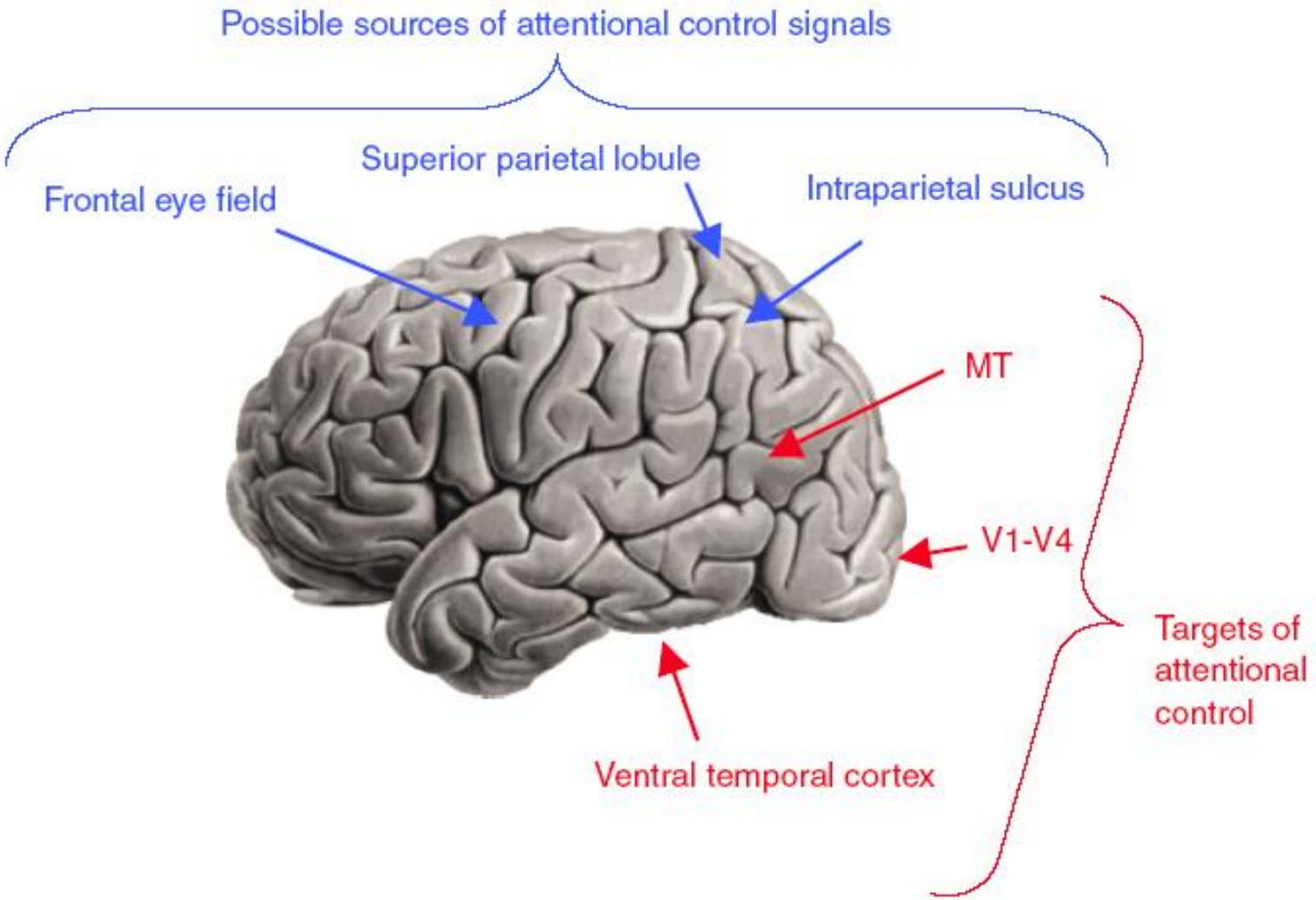
«Ανταγωνισμός» μεταξύ οπτικών ερεθισμάτων

Συγχρονισμός νευρωνικής δραστηριότητας.

$$y_{(FS_1)_i}(t+1) = f(V_{(FS_1)_i}, (\bar{g}_{exc_{IN}} w_{exc_{IN}} \sum_j^N f(y_{(IN)_j}(t)) + (\bar{g}_{exc_{CDN}} w_{exc_{CDN}} \sum_j^N f(y_{(CDN)_j}(t))))$$

$$y_{X(FS_2)_i}(t+1) = f(V_{X(FS_2)_i}, (\bar{g}_{exc_{FS_1}} w_{exc_{FS_1}} \sum_j^N f(y_{X(FS_1)_j}(t))) + (\bar{g}_{inh} w_{lat-inh_{FS}} \sum_j^M f(y_{A(FS_1)_j}(t))))$$

Top-Down attention

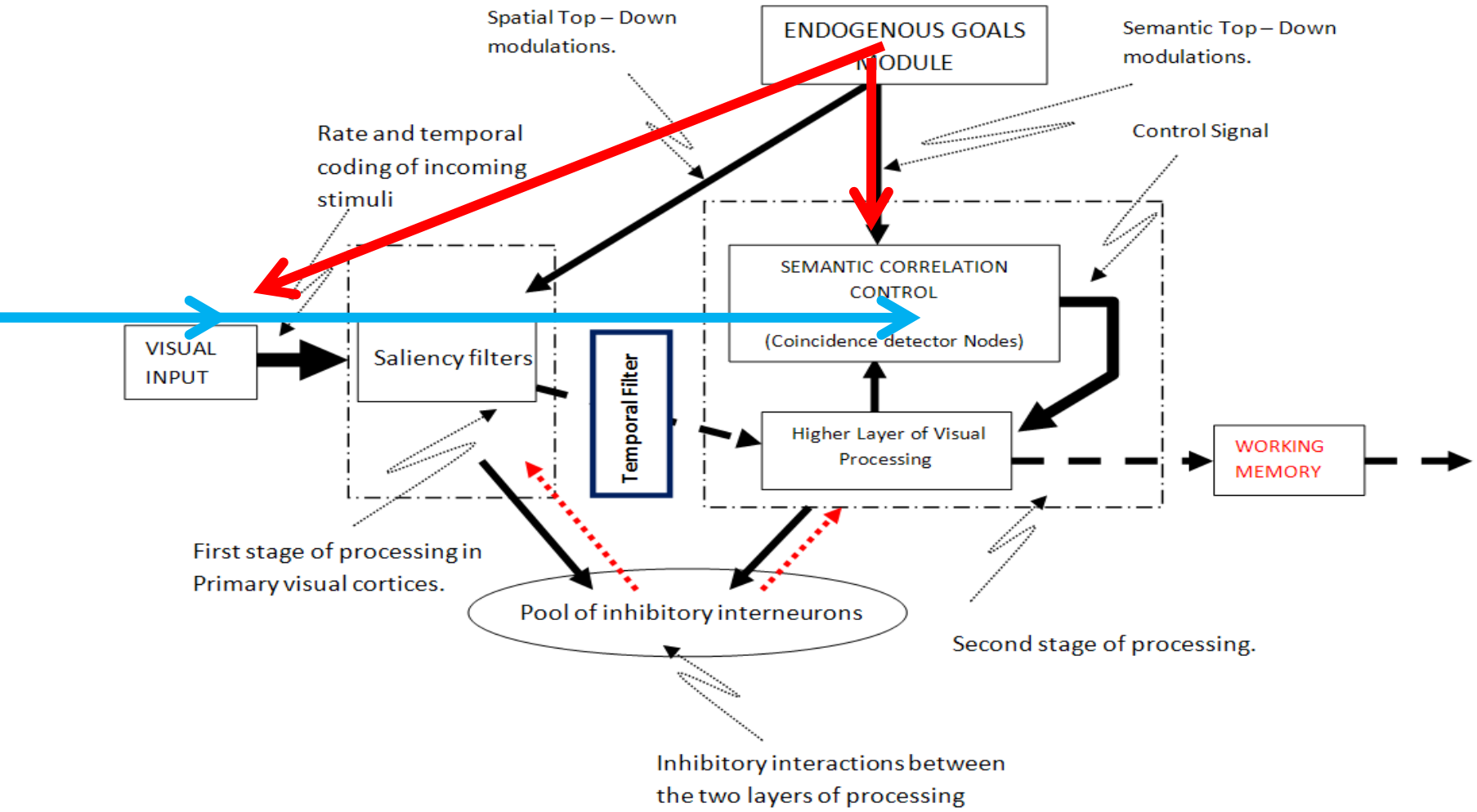


Eric I. Knudsen, **Fundamental Components of Attention,** *Annu. Rev. Neurosci. 2007*

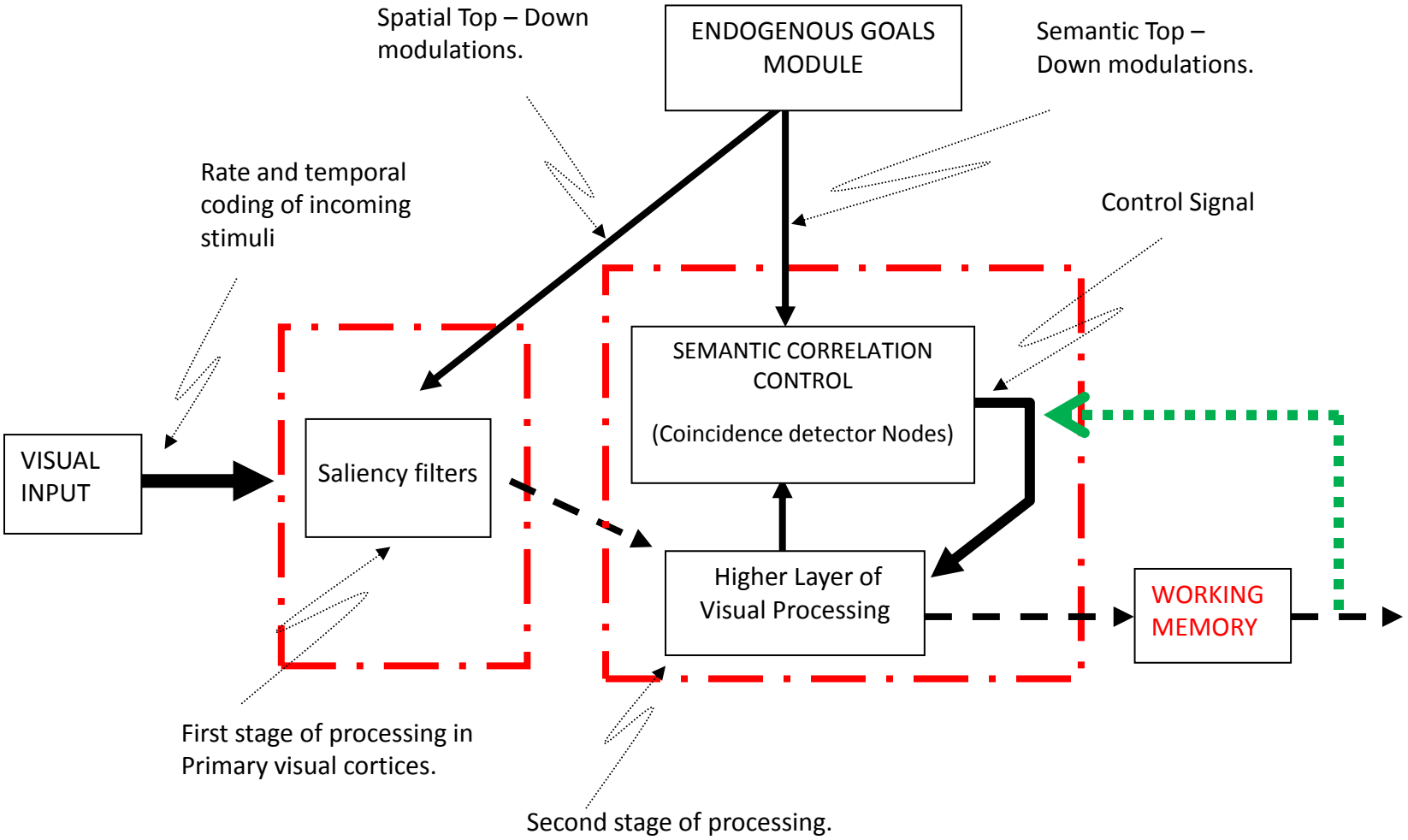
Ενδογενείς επιδράσεις (top down interactions)

Χωρικές νύξεις (spatial cues)

Νύξεις σημασιολογίας (semantic cues)

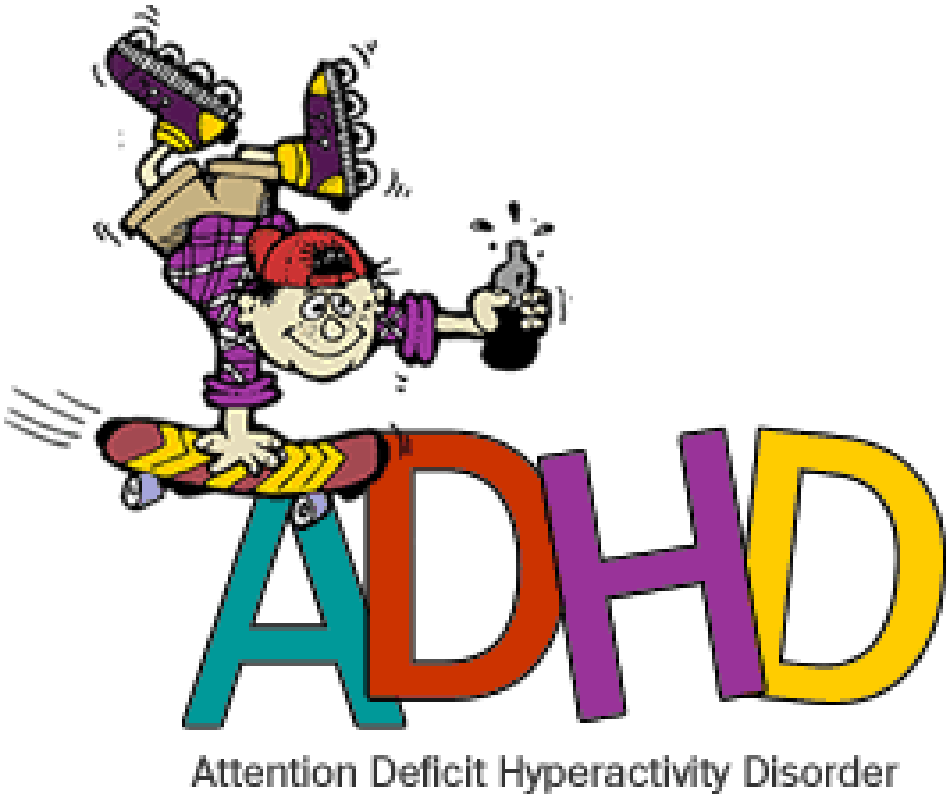


Μαθηματική ανάλυση του μοντέλου



Possible applications of cognitive modeling of visual selective attention

Medical applications…



ADHD is the most commonly studied and diagnosed psychiatric disorder in children, **affecting about 3 to 5% of children globally** with symptoms starting before seven years of age.

Schizophrenia

Schizophrenia is a group of serious brain disorders in which reality is interpreted abnormally…

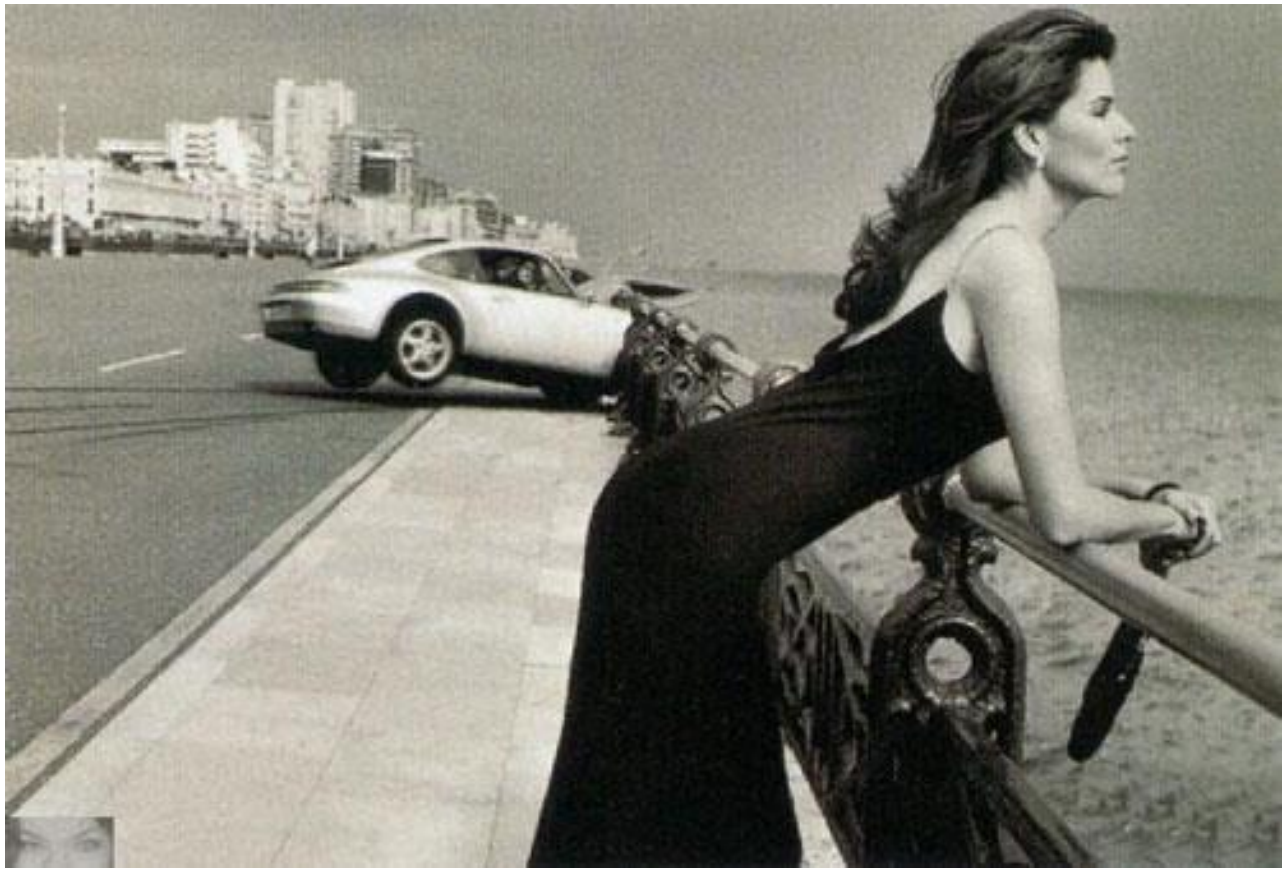
Cognitive and **attentional deficits** have been suggested to play a critical role in the original descriptions of schizophrenia …

Michie PT, Fox AM, Ward PB, Catts SV, McConaghy N: Event-related potential indices of selective attention and cortical lateralization in schizophrenia. *Psychophysiology* 1990; 27:209– 227

Social applications…

Working safety..

Car accidents avoidance etc…



Applications in human computer interactions – robotics…

Applications in computer vision…

Spatial Cognition

Virtual Reality