“We only see what we look at”

(Maurice Merleau Ponty, 1961)

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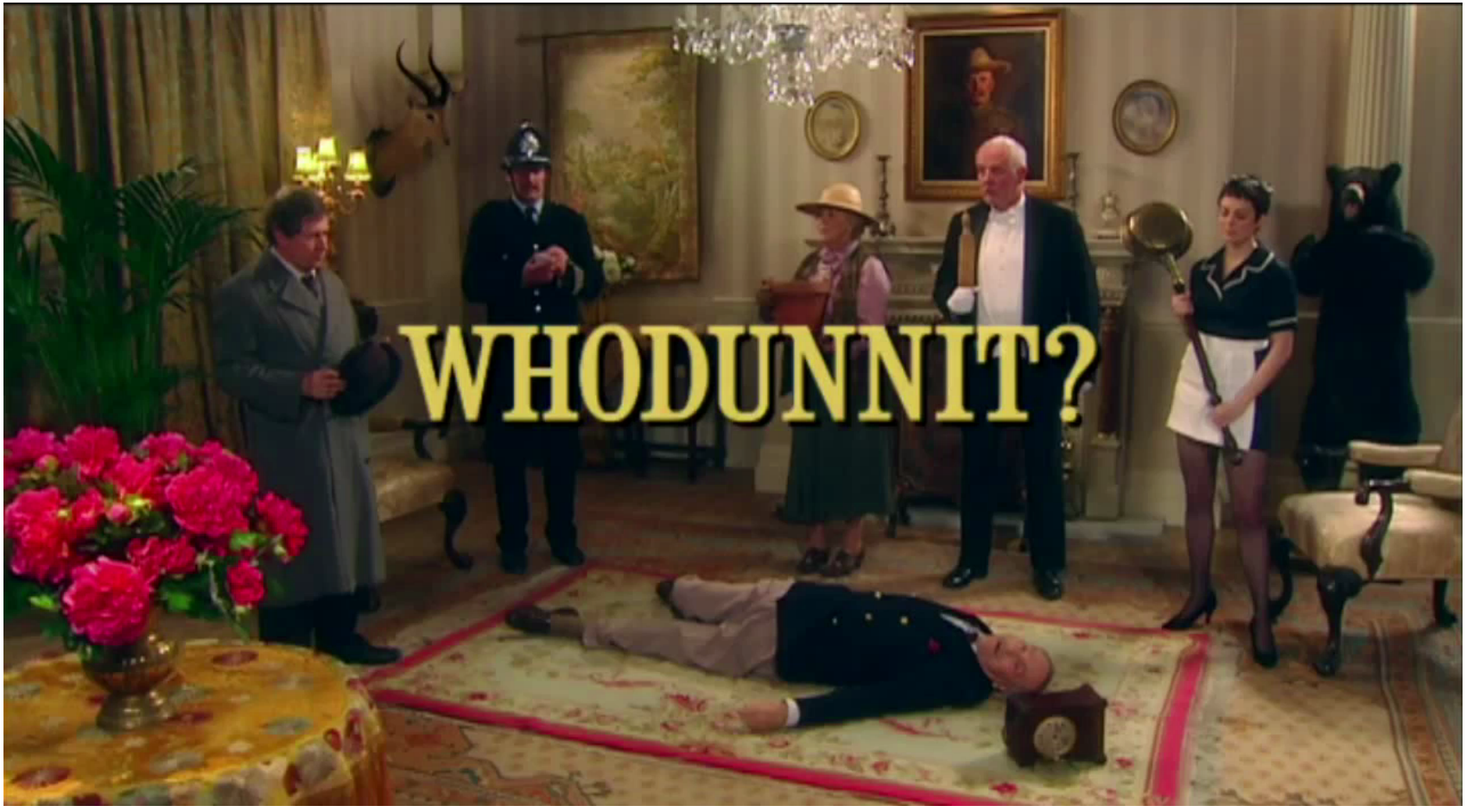
Keep Calm and Do the Test

(Transport for London Campaign, 2008)



On ne voit que ce que l'on regarde

"L'Œil et l'Esprit", Maurice Merleau Ponty, 1961

Everyone knows what attention is. It is the possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies **withdrawal from some things in order to deal effectively with others**, and is a condition which has a real opposite in the confused, dazed, scatterbrained state which in French is called *distraction*, and *Zerstreutheit* in German.

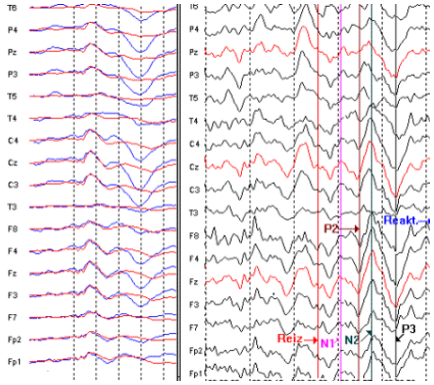
William James, *Principles of Psychology*, 1890

Trying to understand perception by studying only neurons is like trying to understand bird flight by studying only feathers: *it just cannot be done*. In order to understand bird flight, we have to understand aerodynamics; only then do the structure of feathers and the different shapes of birds' wings make sense.

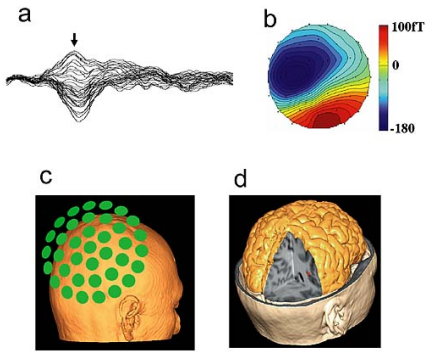
David Marr, *Vision*, 1982

Biological Framework

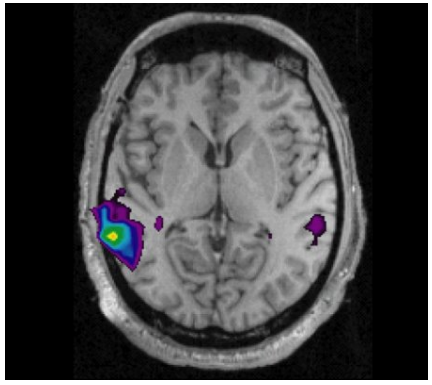
Gathering data, knowledge and facts



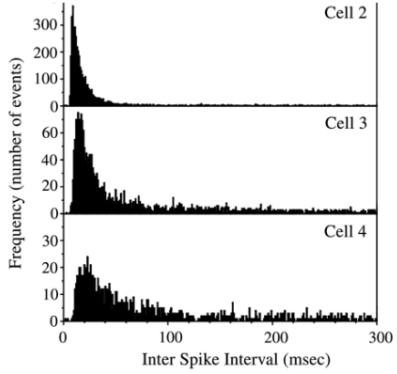
EEG



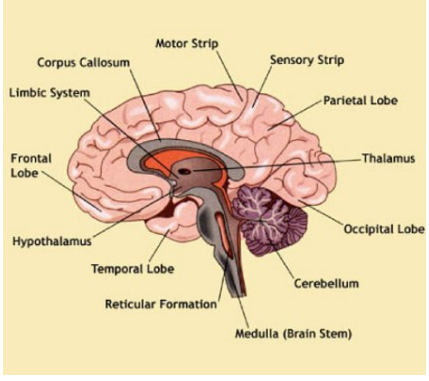
MEG



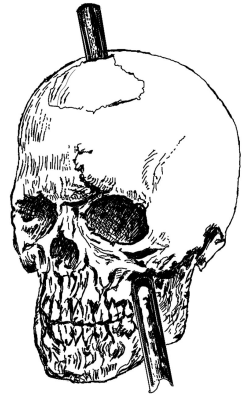
IRMf



Cell recording



Theory and models



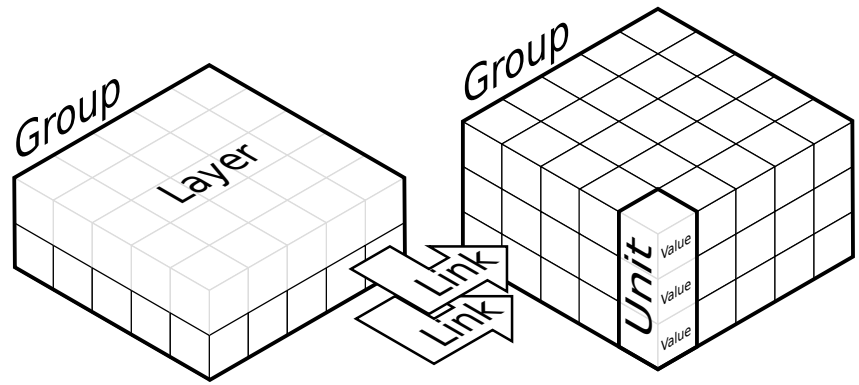
Lesions/Accidents

Computational Framework

Distributed, Asynchronous, Numerical & Adaptive

A unit is a set of arbitrary values that can vary along time under the influence of other units and learning.

- Distributed
  → No central supervisor
- Asynchronous
  → No central clock
- Numerical
  → No symbols
- Adaptive
  → To learn something

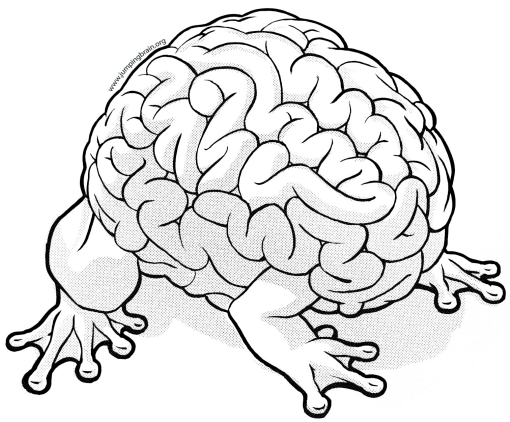


We want to make sure that emerging properties are those of the model and not of the software running the model.

Cognitive Framework

Reclaiming the body

Embodied Cognition



- Embodiment of an organism simultaneously limits and prescribes the types of cognitive processes that are available to it.
- Cognition is deeply rooted in the body's interactions with the world

The continuity principles

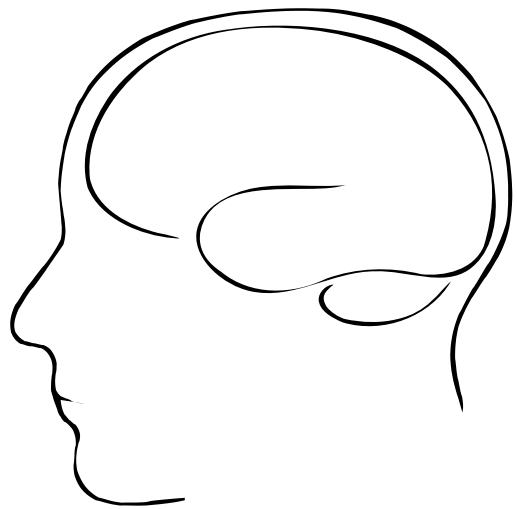
- No obvious link between neural and cognitive levels
- The microscopic discreteness of neural information does not scale up

Philosophical Framework

What is cognition ?

What are the questions ?

- What are the main forms of cognition ?
- What are the minimal mechanisms ?
- What is/are the right biological levels ?
- How do we identify a satisfactory answer ?
- What is the role of the observer ?



The grand illusion of seeing...

Visual Pathways (Felleman & Van Essens, 1991)

The dorsal pathway

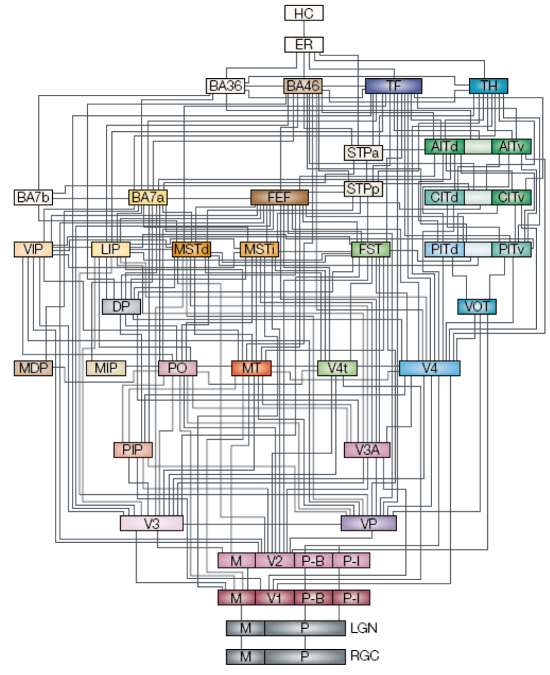
- *Where or How* pathway
- Motion and object locations

The ventral pathway

- *What* pathway
- Form and object representation

The frontal pathway

- Executive control
- Temporal organization of behavior
- Visual Awareness



32 cortical areas, 10 hierarchical levels

Attention

Many forms and expressions

Clinical Description (Sohlberg & Mateer, 1989)

Focused	to respond discretely to a specific stimuli.
Sustained	to maintain a consistent behavioral response
Selective	to maintain attention in the face of distractors
Alternating	to shift focus of attention
Divided	to respond simultaneously to multiple tasks

Cognitive Description

Motor	movements preparation, priming, etc.
Sensory	auditory, visual, proprioception, etc.
Overt	motor response (explicit)
Covert	cognitive response (implicit)
Top-down	goal driven, bias, etc.
Bottom-Up	stimulus driven, pop-out, etc.

Visual Attention

The spotlight metaphor

Attention is the capacity to select a relevant region of the sensory space

- Topological region of the sensory space → spatial attention
- Featural region of the sensory space → feature oriented attention
- Object as such → object oriented attention

Theories of Visual Attention

Inhibition Of Return (IOR, Posner, 1980)

IOR operates to decrease the likelihood that a previsously inspected item in the visual scene will be reinspected

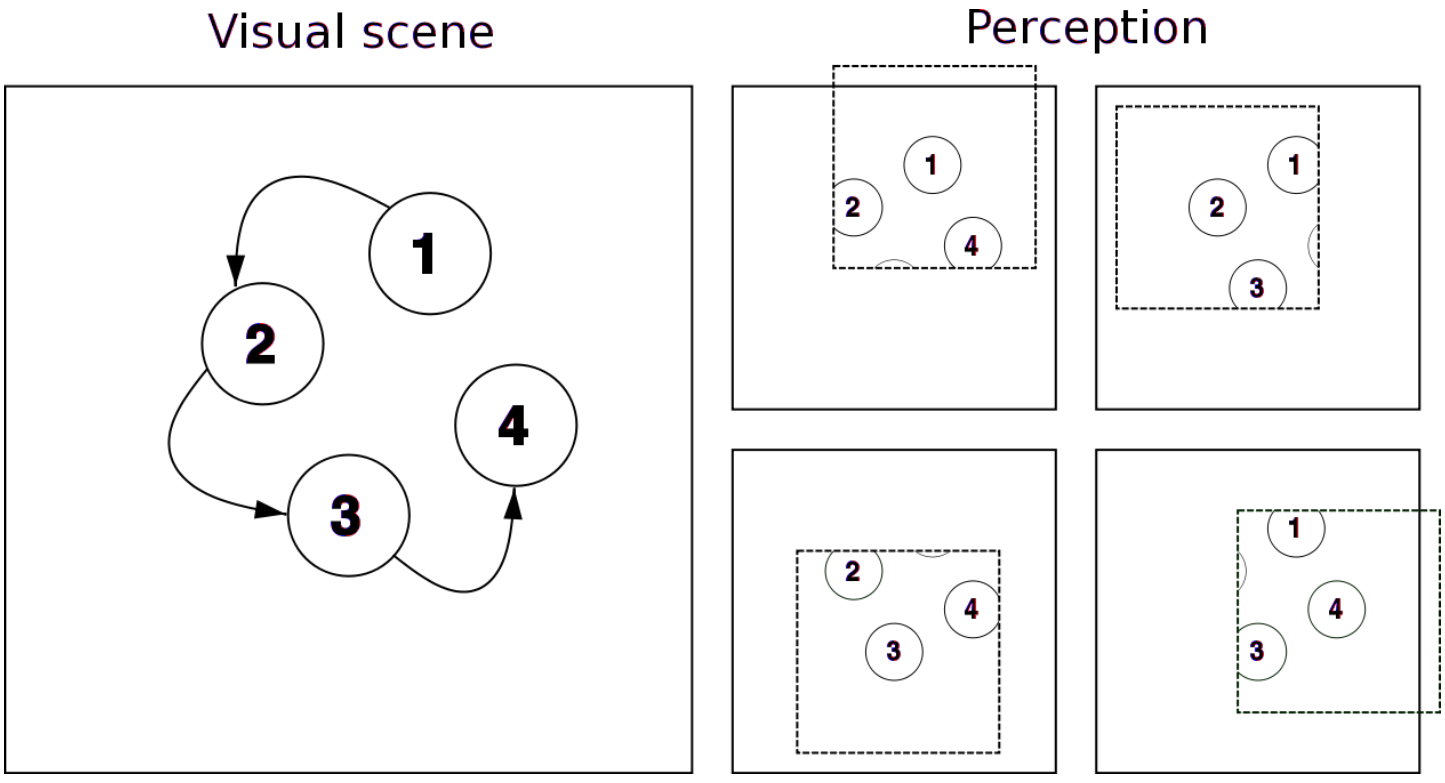
Premotor Theory of Attention (Rizzolati, 1987)

Attention may derive from weaker activation of same fronto-parietal circuits

Saliency Maps (Itti & Koch, 2001)

Saliency map is a topographically arranged map that represents visual saliency of a corresponding visual scene.

Making saccades



Occular saccades lead to drastic changes in visual perception.

Dynamic Neural Fields

(Wilson & Cowan, 1972)

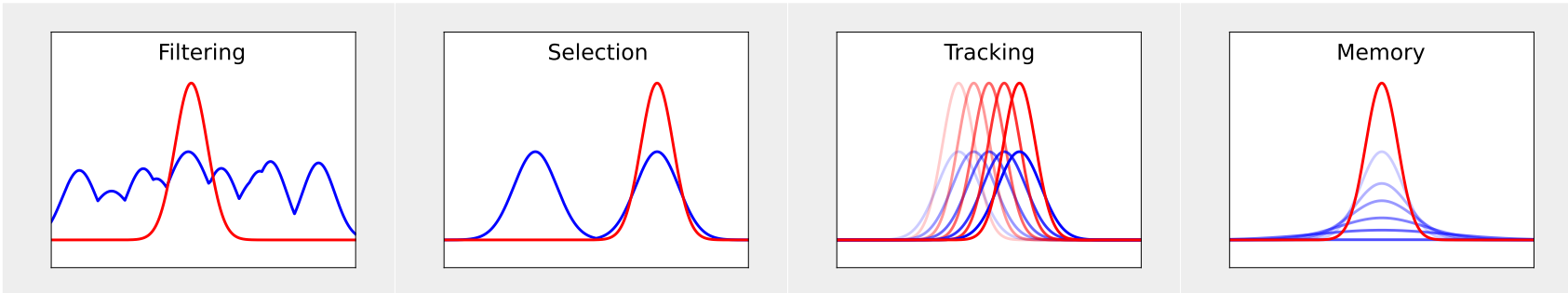
Equation

Let **u(x,t)** be the membrane potential at position **x** and time **t**, **f** a transfer function and **w** a kernel of lateral interaction. The temporal evolution of **u(x,t)** is given by:

$$\tau \cdot \frac{\partial u(x,t)}{\partial t} = -u(x,t) + \int_{-\infty}^{+\infty} w(x-y) \cdot f(u(y,t))\, dy + I(x) + h$$

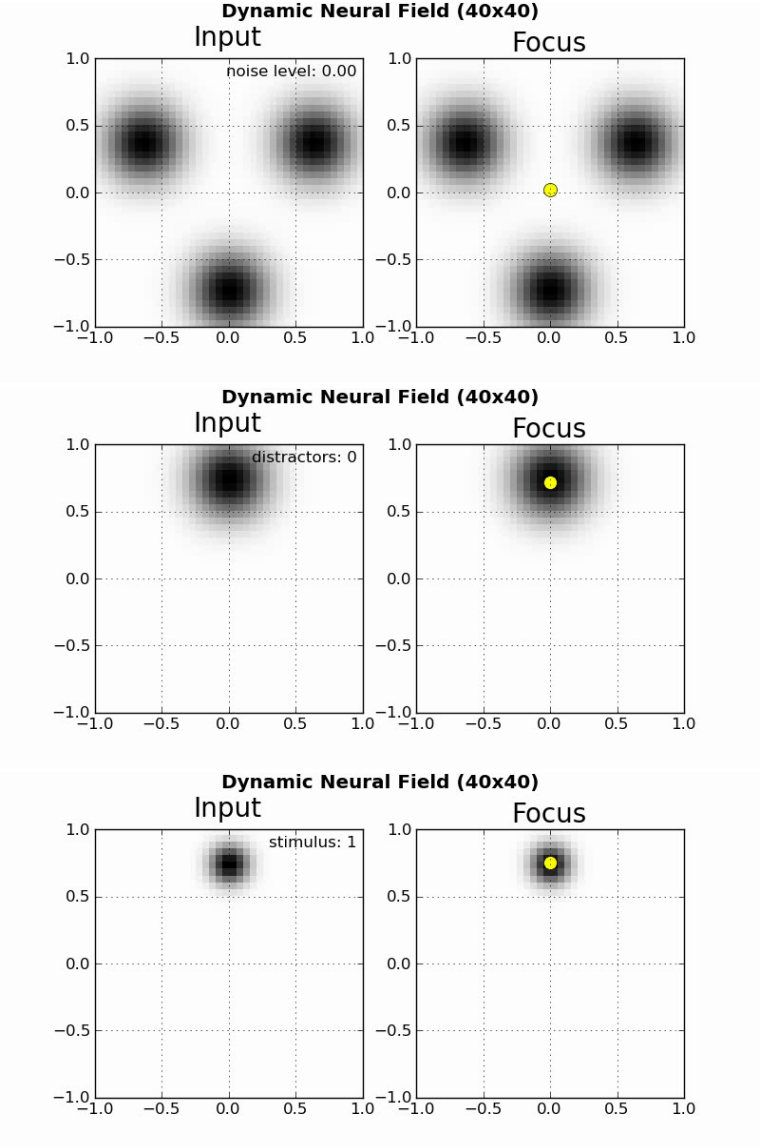
- τ: time constant
- $-u(x,t)$: leak term
- $w(x-y) \cdot f(u(y,t))$: lateral interactions
- $I(x)$: input
- h: resting potential

Some properties

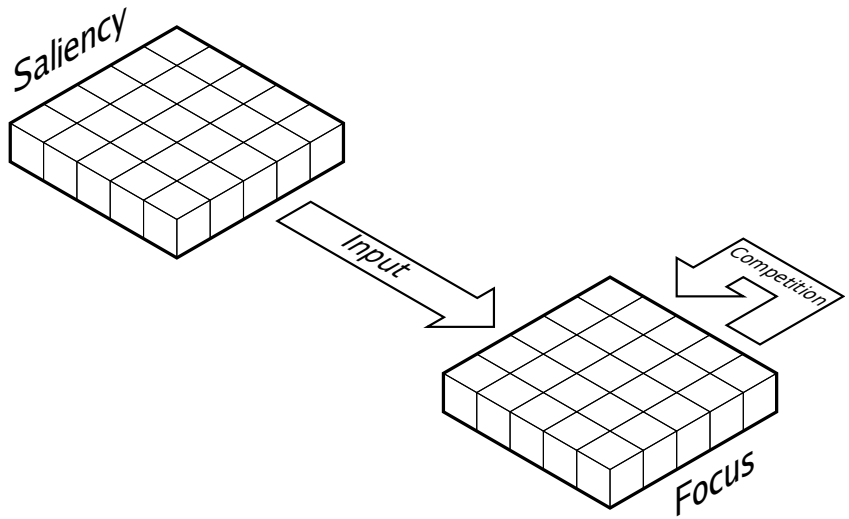


Visual Tracking

(Rougier & Vitay, 2006)

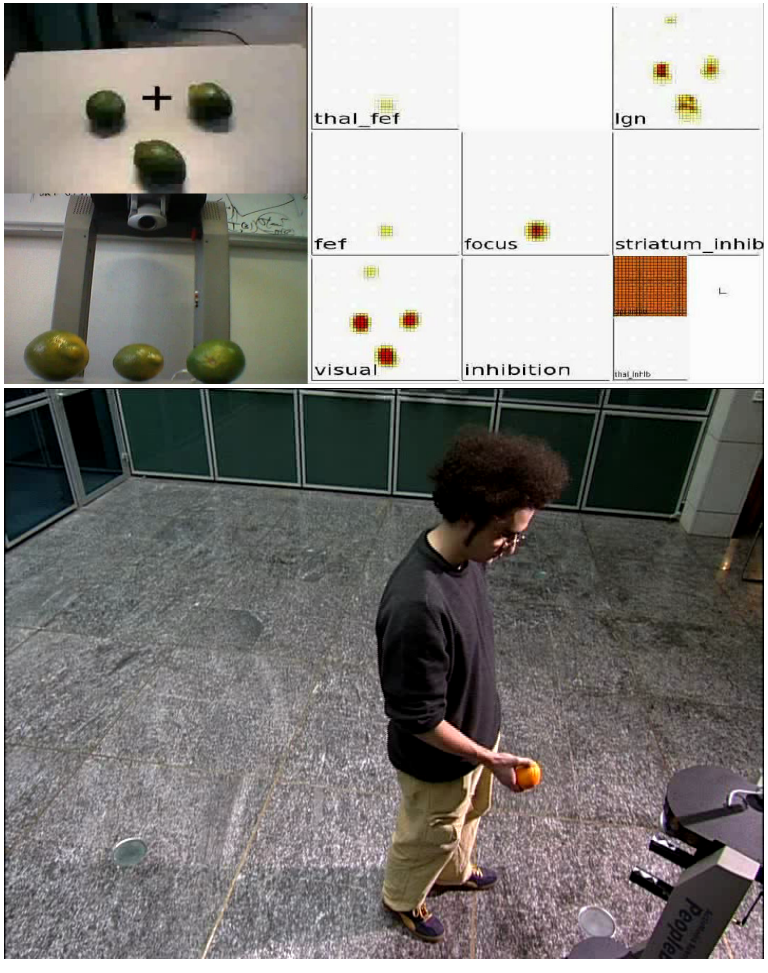


- Simple model of visual tracking
- Robustness to noise & distractors
- Dynamic & reactive behavior

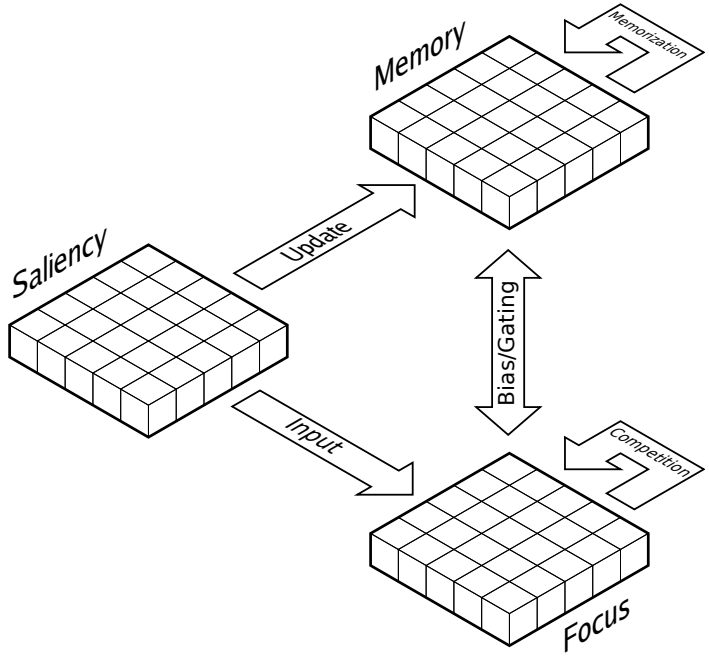


Visual attention

(Vitay & Rougier, 2005)



- Dynamic Working memory
- Biased competition
- Sequential behavior



Visual anticipation

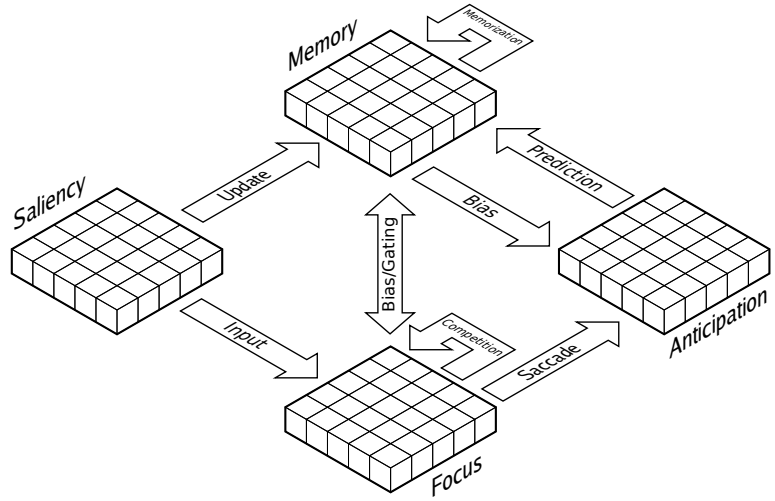
(Fix et al., 2007)

Spatial reference

- Independent of eye movements
- Eye-centered

Action in perception

- To anticipate the consequences of own actions
- To update working memory accordingly

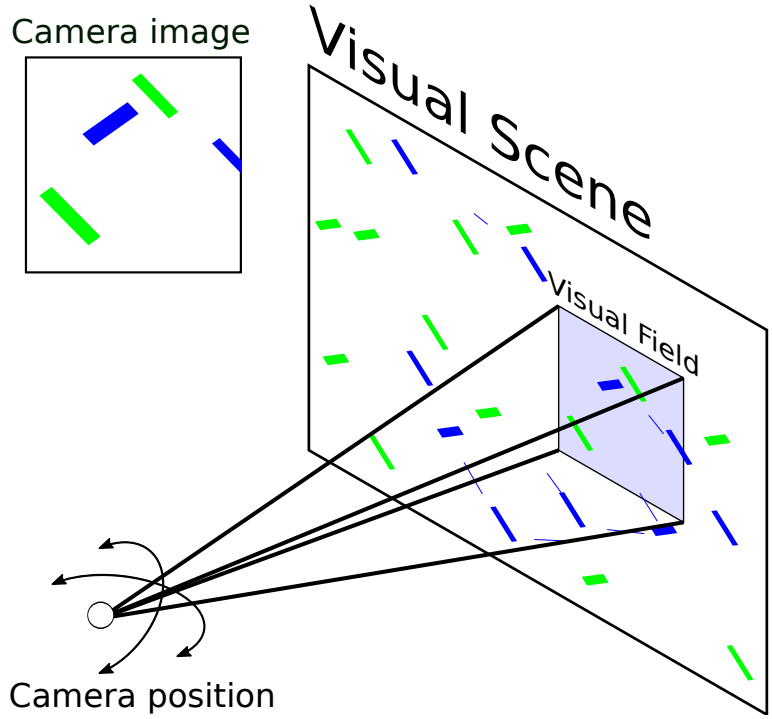


A model of covert and overt attention

(Fix et al., 2010)

Search task

The camera is placed in front of a visual scene and is able to pan and tilt. The task can be either to look for a specific orientation or colour or to look for a conjunction of such features.



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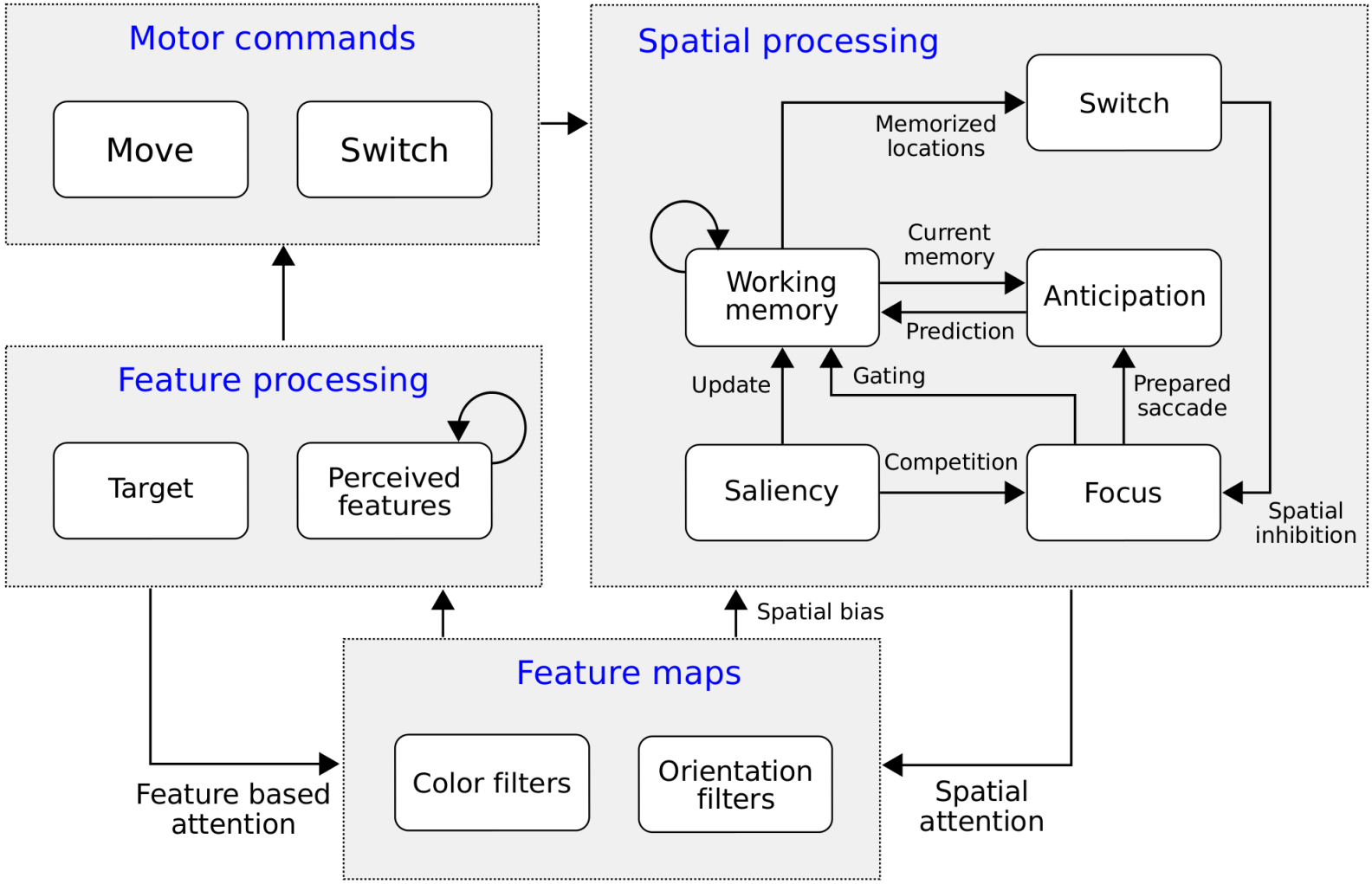

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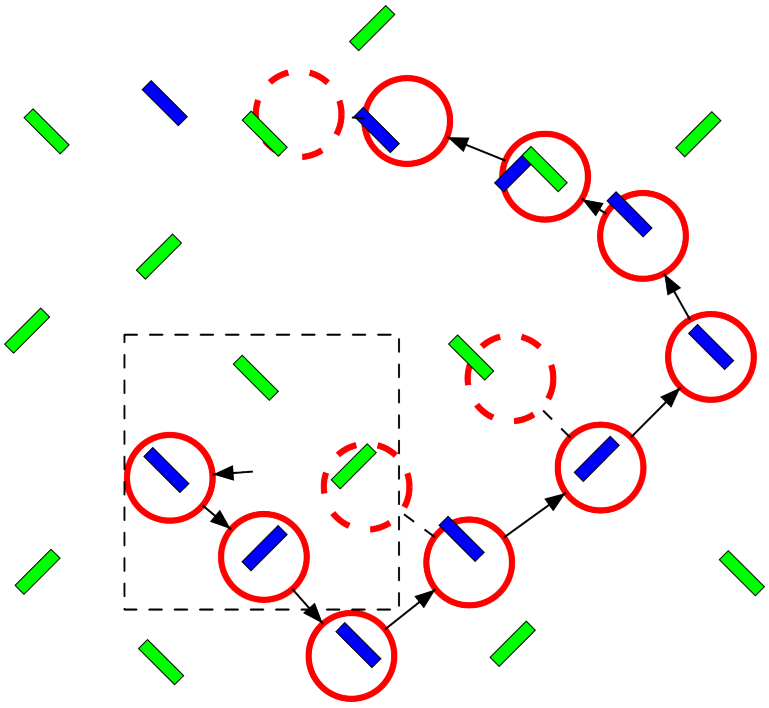
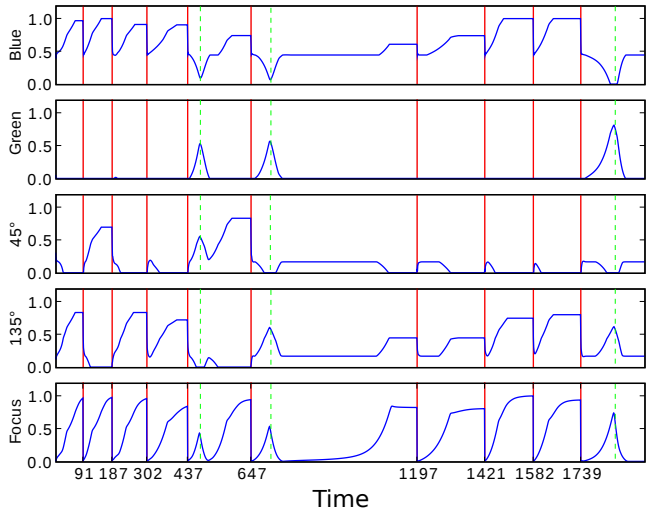




- Feature based attention facilitates processing of relevant features
- Spatial based attention facilitates processing of relevant region
- Working memory prevents to explore already seen location
- Model exhibits both overt and covert attention using same substrate

Toward the organization of visual behavior

A bottom-up sequential exploratory behavior has emerged from distributed & numeric computation but...

From an automated behavior...

- Visual attention can be spatialy or featurally biased
- Most salient stimulus are likely to be attended
- How to circumvent this *automated* behavior ?

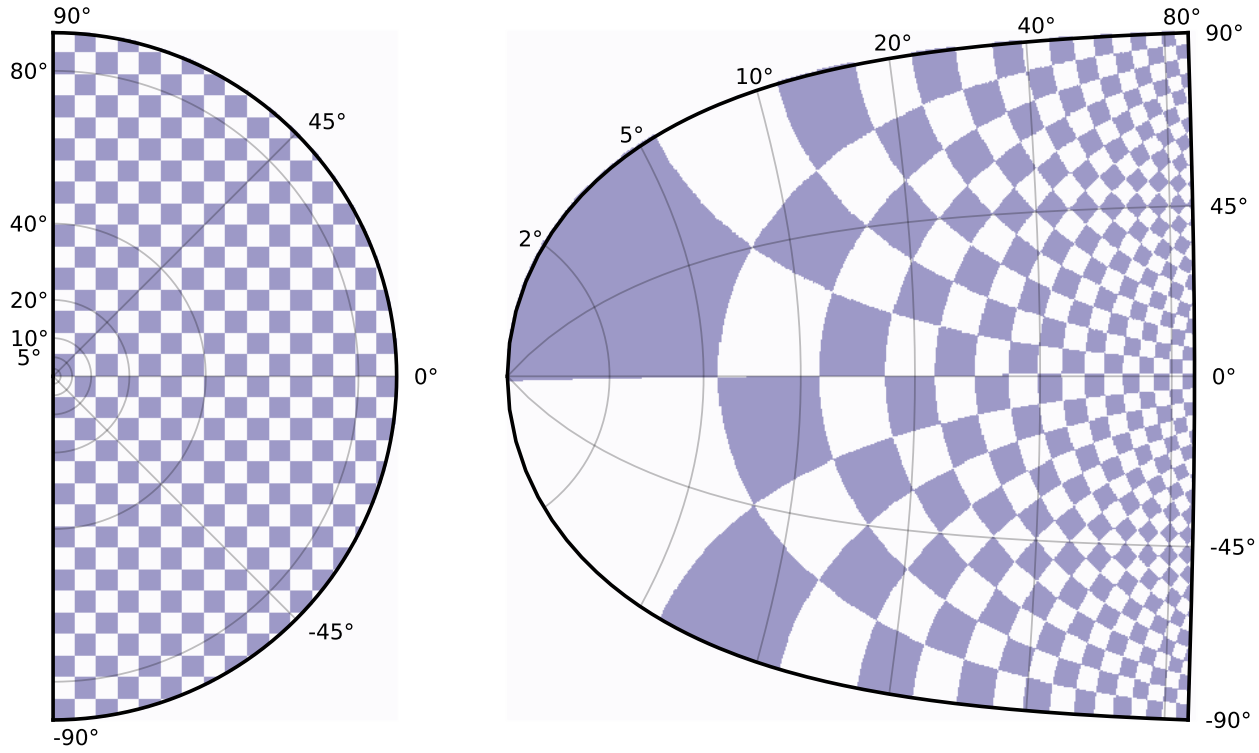
...to a motivated one

- To consider saccadic behavior as a motivated exploration
- To make hypothesis about the world make saccades to try to confirm them

So far, so good

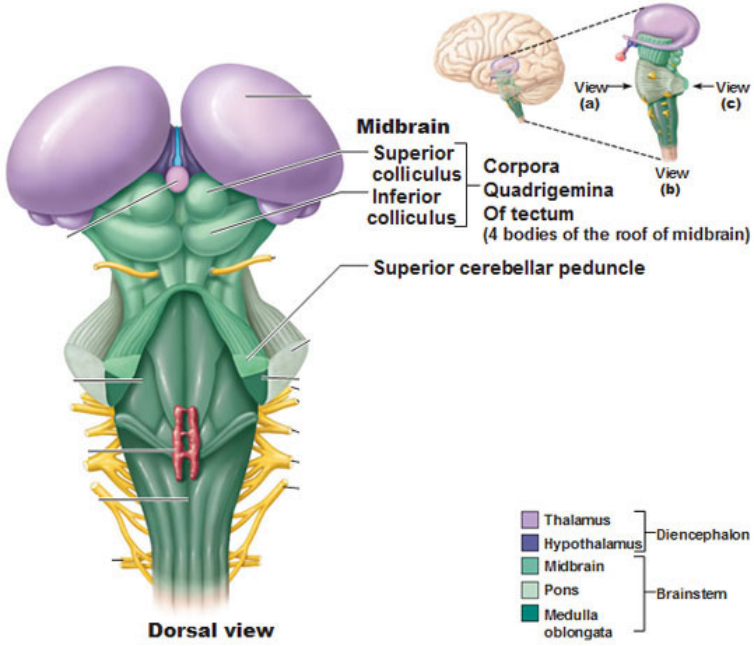
But...

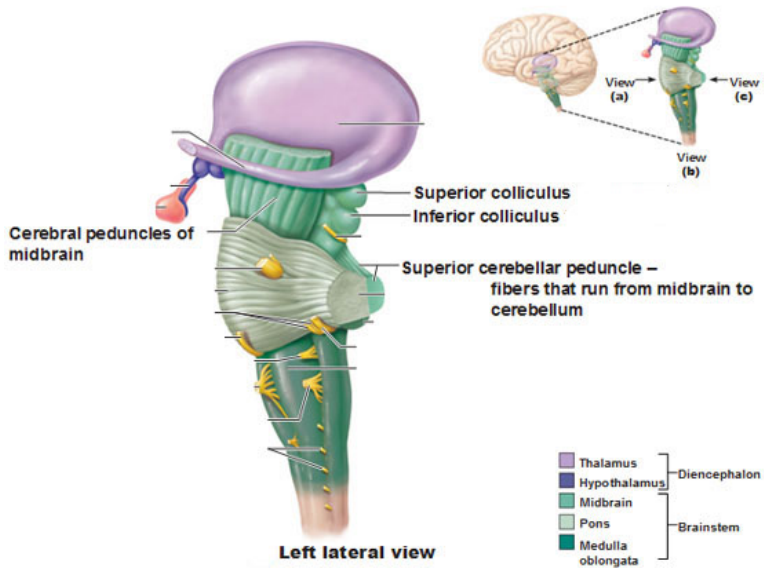
Things are a bit more complicated...



Superior Colliculus

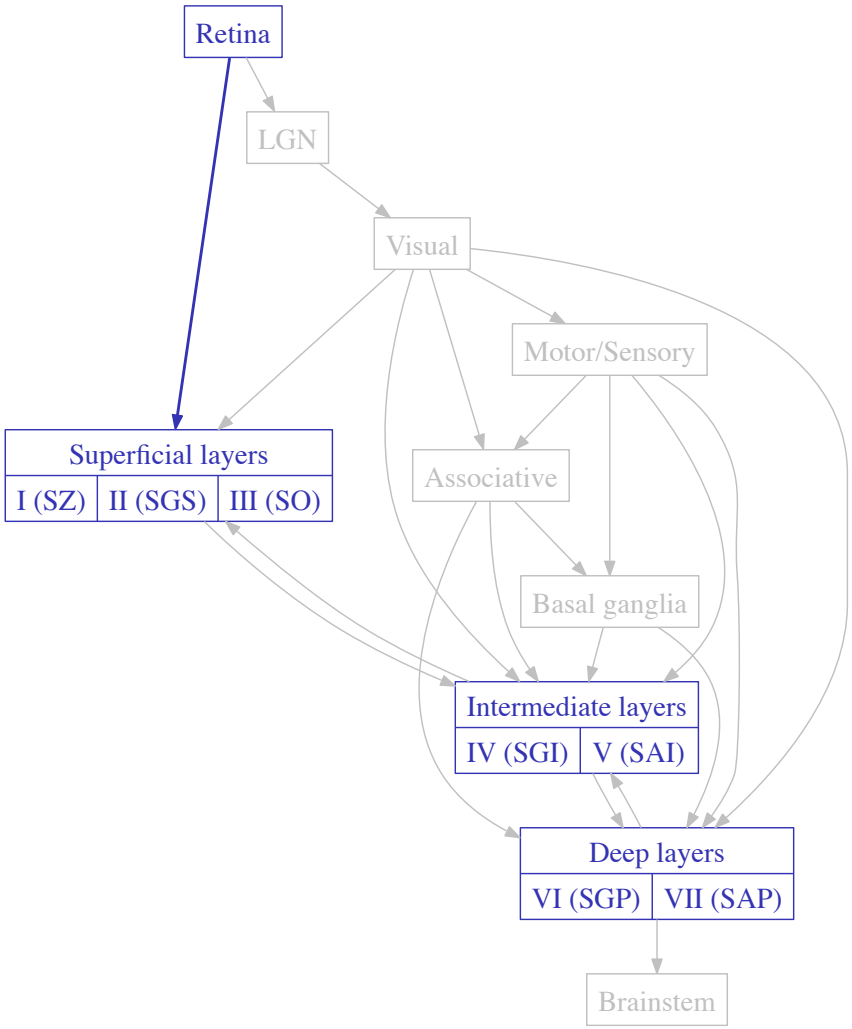
Brain Stem - Midbrain





Superior colliculus

Structure & paths



- **I (SZ)**: stratum zonale
- **II(SGS)**: stratum griseum superficiale
- **III (SO)**: stratum opticum
- **IV (SGI)**: stratum griseum intermediale
- **V (SAI)**: stratum album intermediale
- **VI (SGP)**: stratum griseum profundum
- **VII (SAP)**: stratum album profundum

Superior colliculus

A lot of questions

How are saccades encoded

- Population coding ? sum ? average ?
- What level of precision ?
- What does the receptive fields look like ?
- What is the influence of lesions ?

How decision is made ?

- What if two stimuli are presented ?
- What are the preferred stimuli ?

What is the dynamic ?

- What is the influence of stimulus size, magnitude or position ?
- What is the influence of distractors ?

Many computational models

A set of common hypotheses

Logarithmic projection

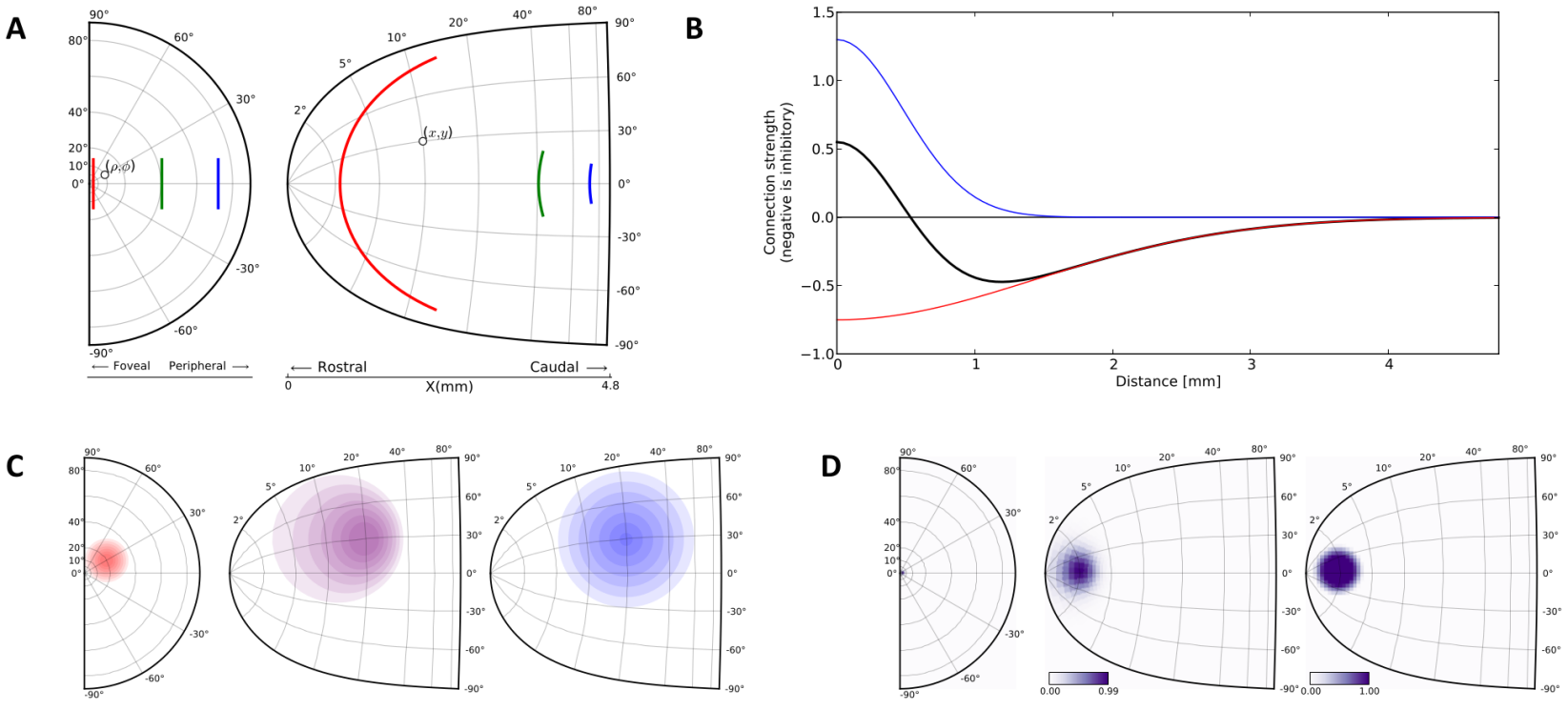
- (Optican 1995)
- (Lefèvre 1998)
- (Trappenberg 2001)
- (Nakahara, 2006)
- (Marino, 2008)
- ...

Homogeneous computation

- (Droulez & Berthoz, 1991)
- (Arai et al., 1994)
- (Gancarz & Grossberg, 1999)
- (Trappenberg, 2001)
- (Schneider & Erlhager, 2002)
- (Nakahara et al., 2006)
- (Marino 2012)
- ....

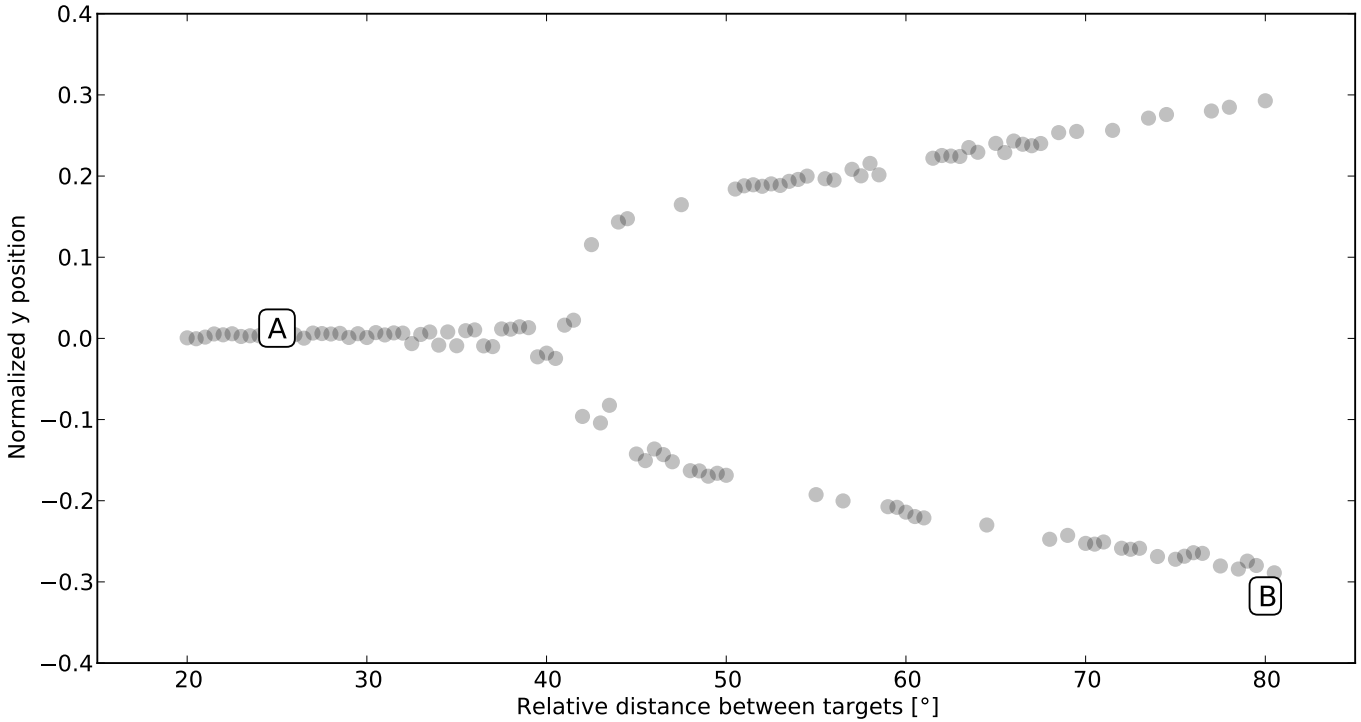
A minimal model

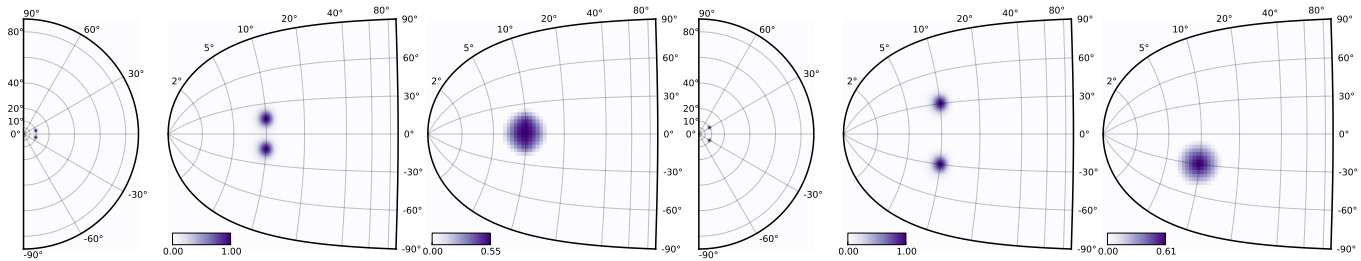
(Taouali et al, in prep)



Decision

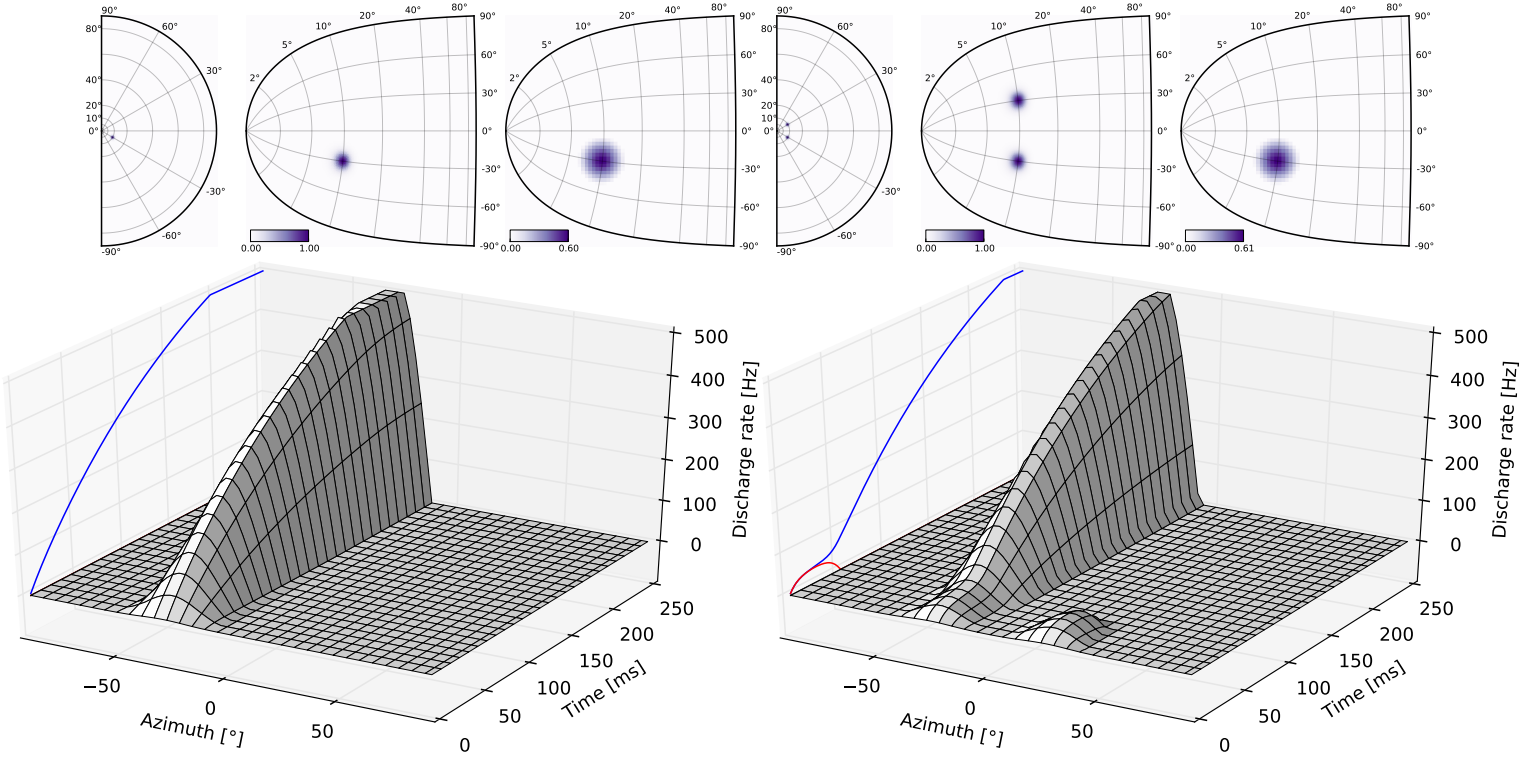
Where to look ?





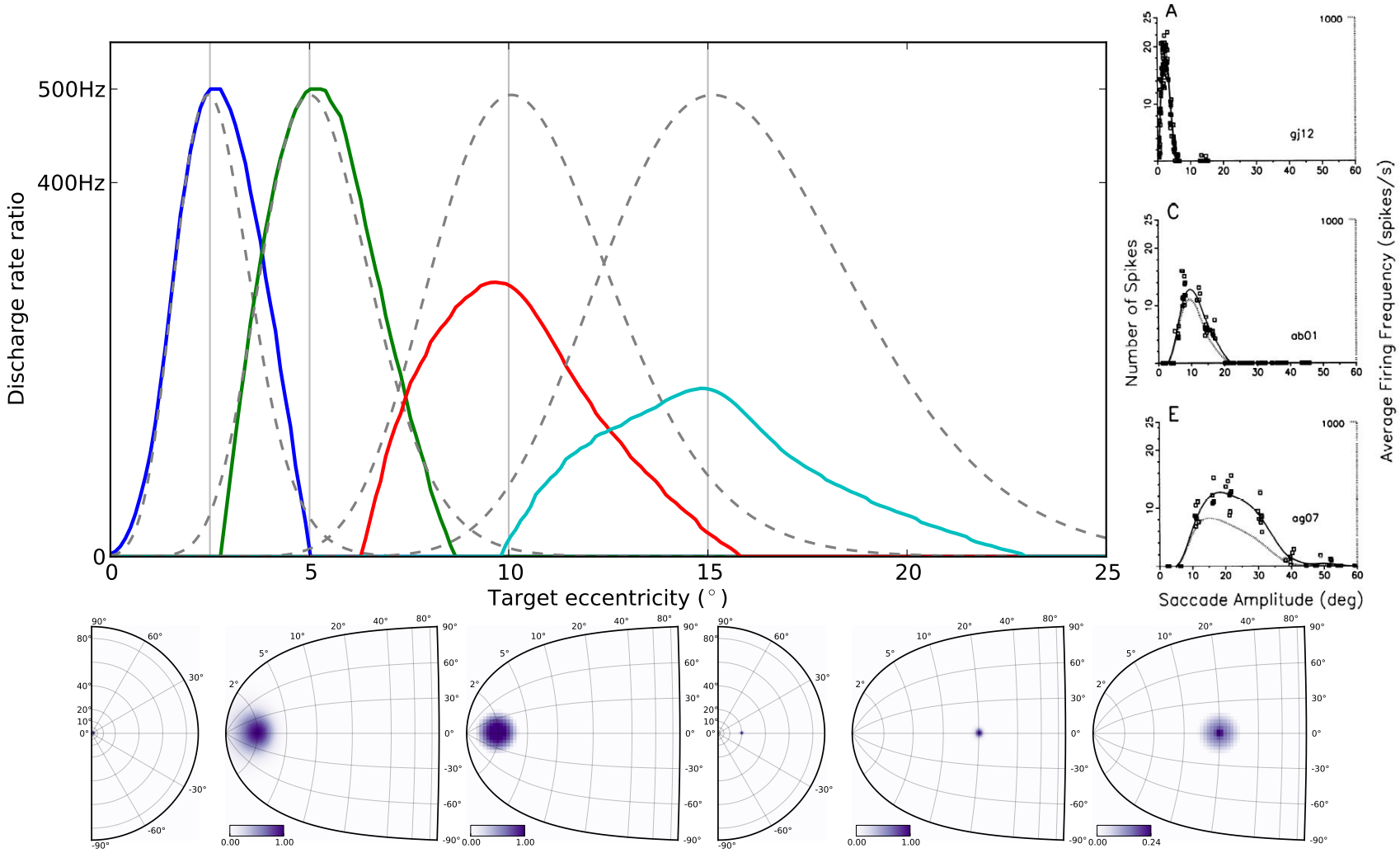
Dynamics

Latency effect



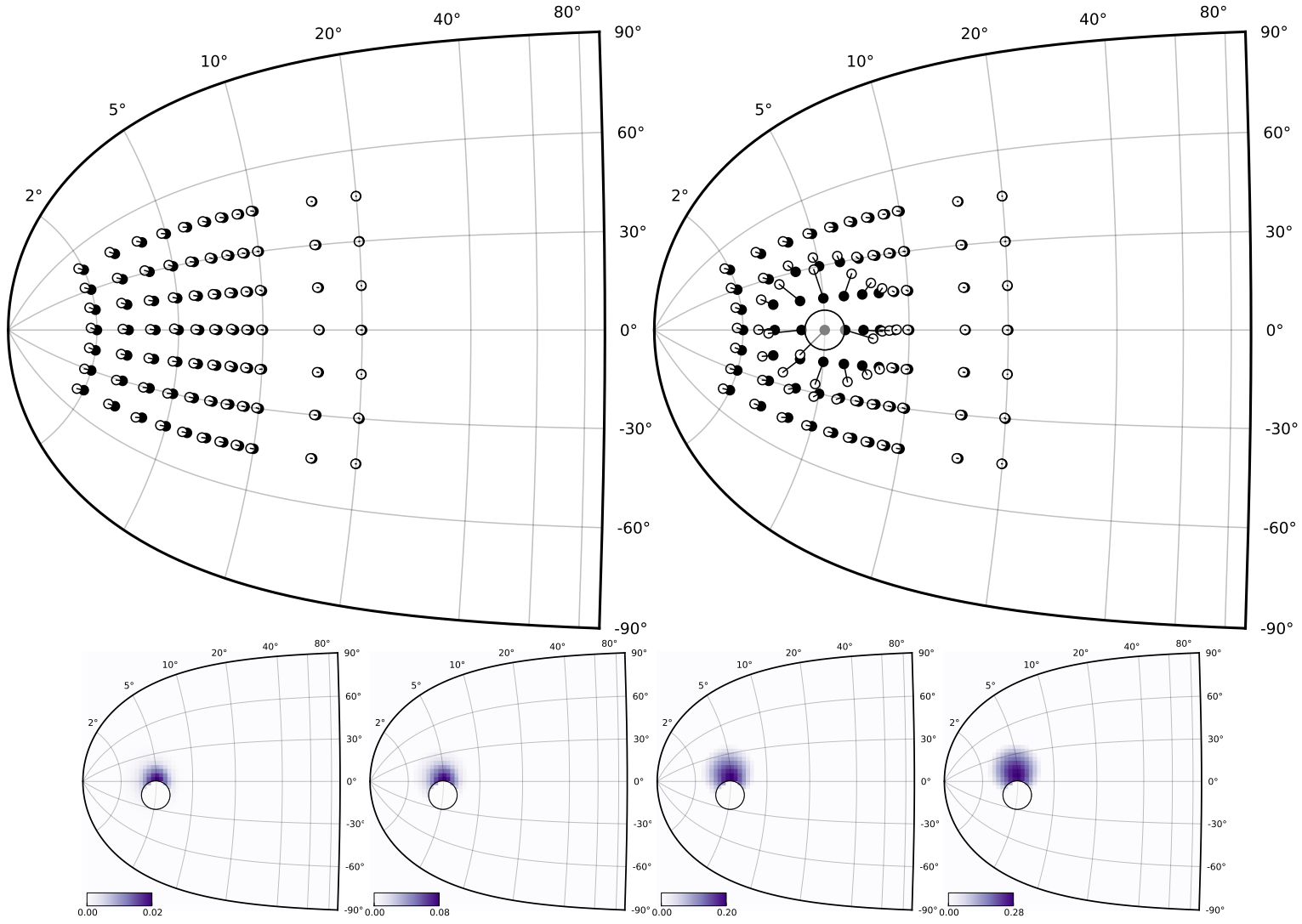
Receptive fields

Rostrally sharper & stronger, caudaly broader & weaker



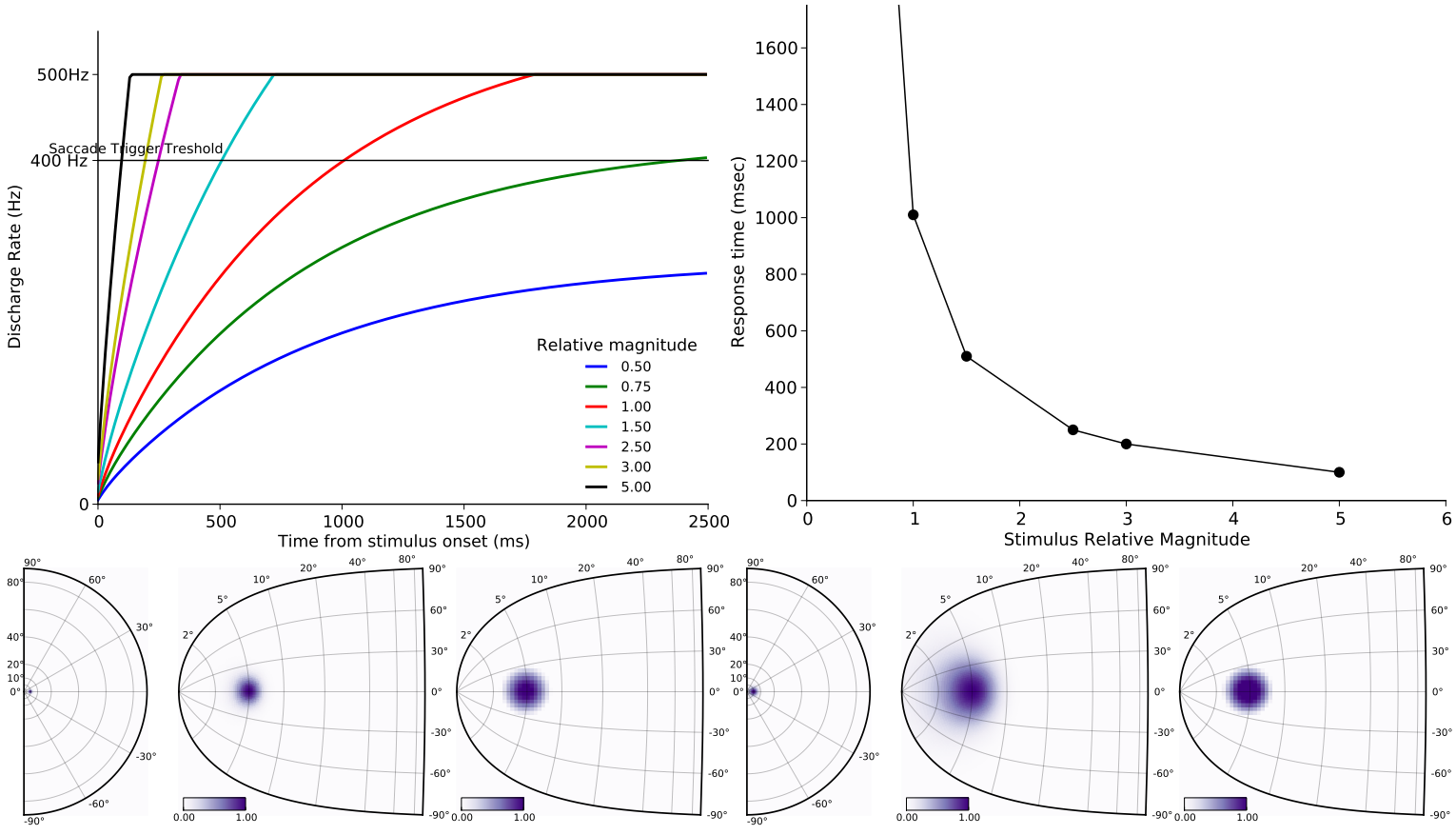
Encoding precision

and lesion effect



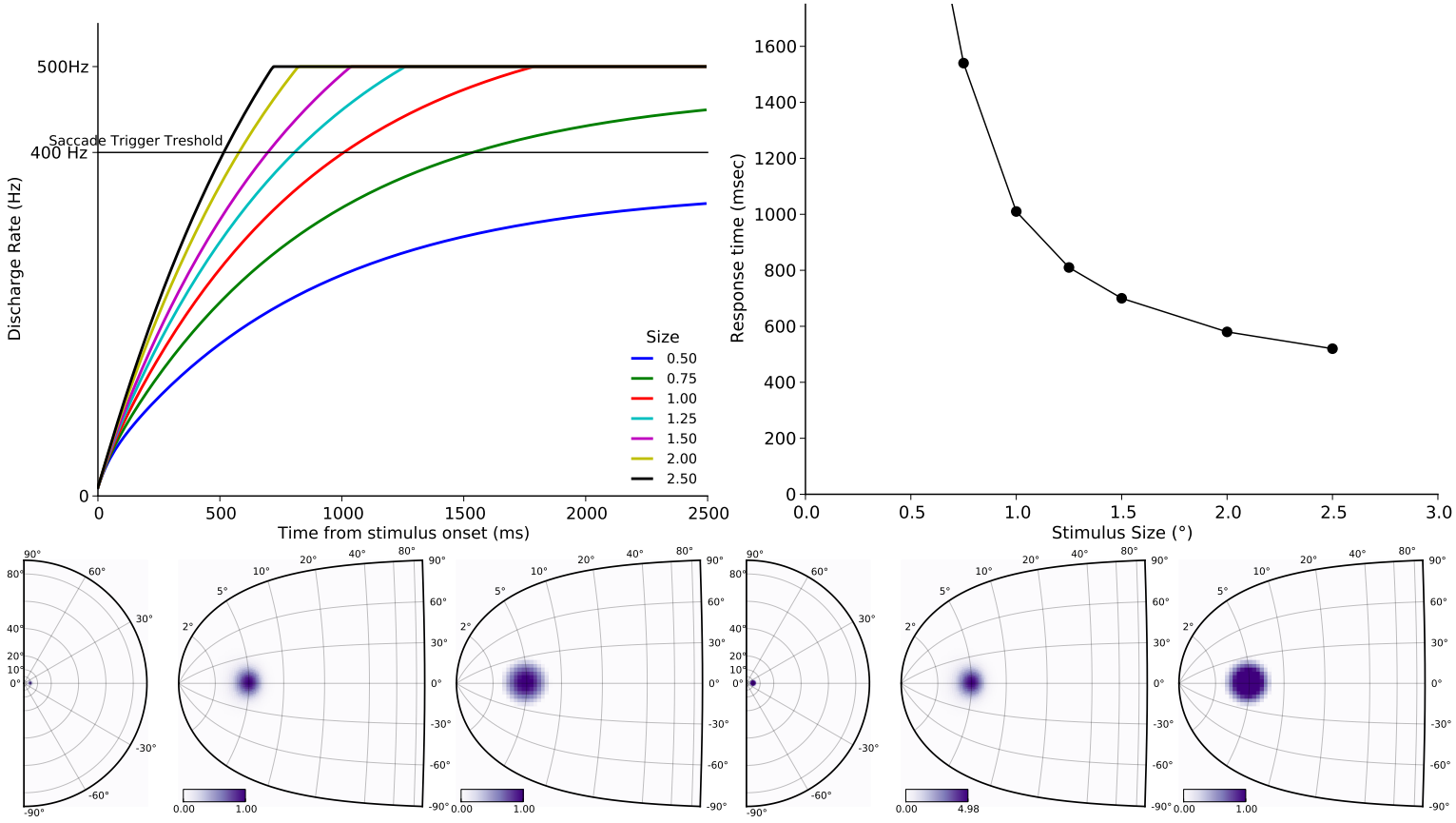
Influence of stimuli size

The bigger, the faster



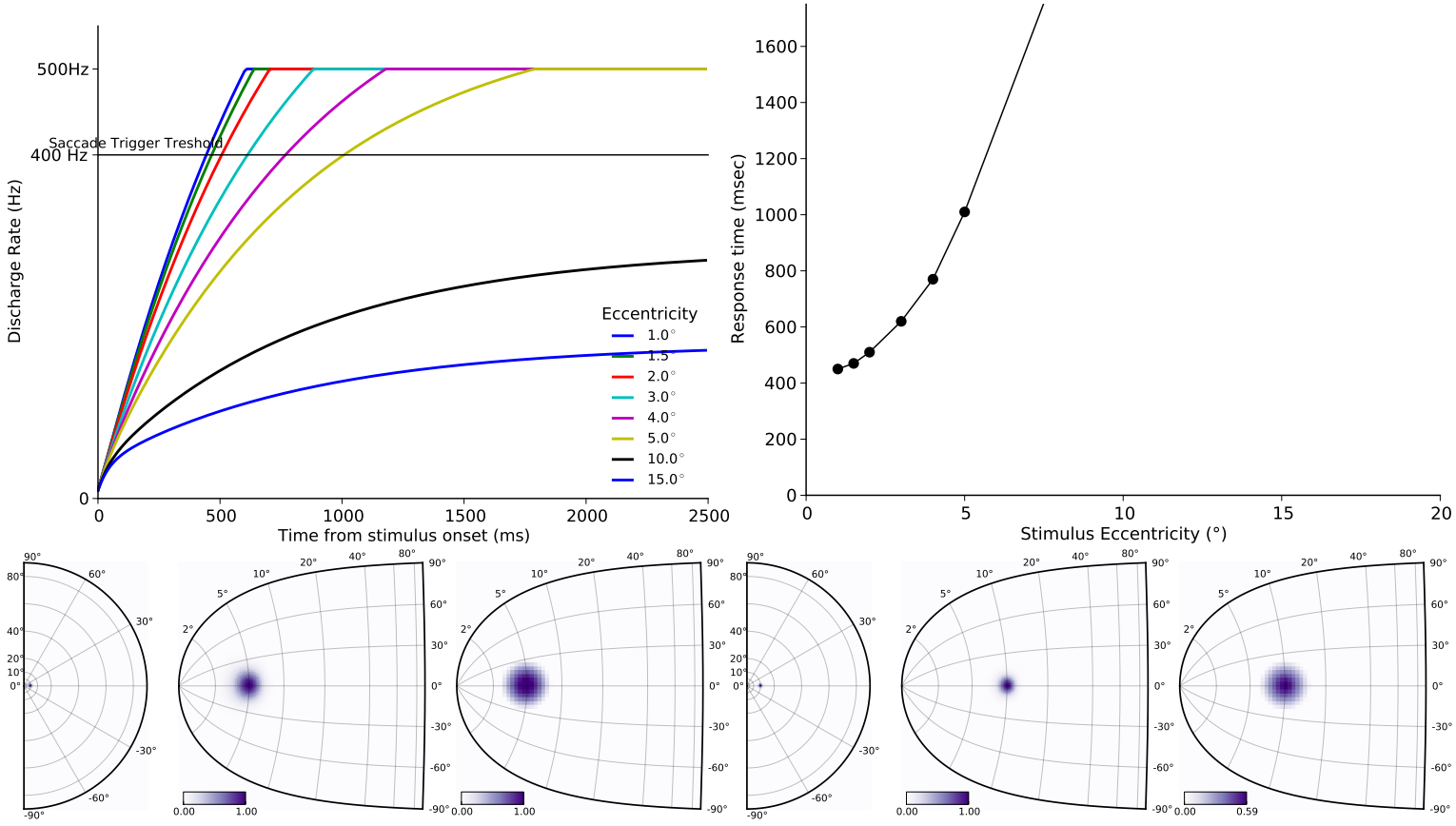
Influence of stimuli magnitude

The stronger, the faster



Influence of stimuli eccentricity

The nearer, the faster



What did we learn so far ?

Ockham is good, Gillette is bad

A simple model

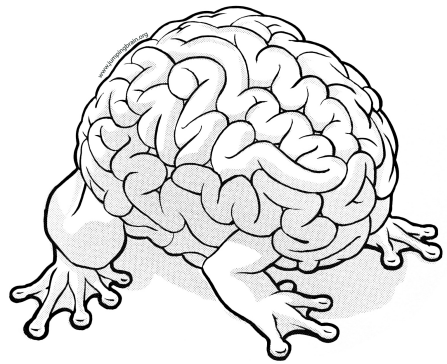
- Topographic projection
- Local excitation / global inhibition

A numerical model

- A population based model
- Local rules and homogenous units

An embodied model

- A dynamical system
- A structural decision



Conclusion

Beyond mere computation

Major cognitive and behavioral functions emerge from adaptive sensorimotor loops involving the external world, the body and the brain. We study, model and implement such loops and their interactions toward a fully autonomous behavior. With such a systemic approach, we mean that such complex systems can only be truly apprehended as a whole and in natural behavioral situation.

Mnemosyne project-team, INRIA Bordeaux, 2012

Brain, body & cognition

- Embodiment constrains cognition
- Emotions play a critical role
- Behavior is motivated

New questions arise

- How to understand our own models ?
- How do we identify behavior ?
- What is the critical mass ?

Collaborators

- **Frédéric Alexandre** (Head of Mnemosyne)
- **Julien Vitay** (former PhD student)
- **Jérémy Fix** (former PhD student)
- **Wahiba Taouali** (former PhD student)




QUESTIONS

FOUND IN GOOGLE AUTOCOMPLETE

WHY DO WHALES JUMP
WHY ARE WITCHES GREEN
WHY ARE THERE MIRRORS ABOVE BEDS
WHY DO I SAY UH
WHY IS SEA SALT BETTER
WHY ARE THERE TREES IN THE MIDDLE OF FIELDS
WHY IS THERE NOT A POKEMON MMO
WHY IS THERE LAUGHING IN TV SHOWS
WHY ARE THERE DOORS ON THE FREEWAY
WHY ARE THERE SO MANY SVCHOST.EXE RUNNING
WHY AREN'T THERE ANY COUNTRIES IN ANTARCTICA
WHY ARE THERE SCARY SOUNDS IN MINECRAFT
WHY IS THERE KICKING IN MY STOMACH
WHY ARE THERE TWO SLASHES AFTER HTTP
WHY ARE THERE CELEBRITIES
WHY DO SNAKES EXIST
WHY DO OYSTERS HAVE PEARLS
WHY ARE DUCKS CALLED DUCKS
WHY DO THEY CALL IT THE CLAP
WHY ARE KYLE AND CARTMAN FRIENDS
WHY IS THERE AN ARROW ON AANG'S HEAD
WHY ARE TEXT MESSAGES BLUE
WHY ARE THERE MUSTACHES ON CLOTHES
WHY ARE THERE MUSTACHES ON CARS
WHY ARE THERE MUSTACHES EVERYWHERE
WHY ARE THERE SO MANY BIRDS IN OHIO
WHY IS THERE SO MUCH RAIN IN OHIO
WHY IS OHIO WEATHER SO WEIRD
WHY ARE THERE MALE AND FEMALE BIKES
WHY ARE THERE BRIDESMAIDS
WHY DO DYING PEOPLE REACH UP
WHY AREN'T THERE VARICOSE ARTERIES
WHY ARE OLD KLINGONS DIFFERENT
WHY ARE THERE TINY SPIDERS IN MY HOUSE
WHY DO SPIDERS COME INSIDE
WHY ARE THERE HUGE SPIDERS IN MY HOUSE
WHY ARE THERE LOTS OF SPIDERS IN MY HOUSE
WHY ARE THERE SPIDERS IN MY ROOM
WHY ARE THERE SO MANY SPIDERS IN MY ROOM
WHY DO SPIDER BITES ITCH
WHY IS DYING SO SCARY
WHY IS THERE NO GPS IN LAPTOPS
WHY DO KNEES CLICK
WHY AREN'T THERE E GRADES
WHY IS ISOLATION BAD
WHY DO BOYS LIKE ME
WHY DON'T BOYS LIKE ME
WHY IS THERE ALWAYS A JAVA UPDATE
WHY ARE THERE RED DOTS ON MY THIGHS
WHY IS LYING GOOD
WHY IS PROGRAMMING SO HARD
WHY IS THERE A 0 OHM RESISTOR
WHY DO AMERICANS HATE SOCCER
WHY DO RHYMES SOUND GOOD
WHY DO TREES DIE
WHY IS THERE NO SOUND ON CNN
WHY AREN'T POKEMON REAL
WHY AREN'T BULLETS SHARP
WHY DO DREAMS SEEM SO REAL

WHY ARE THERE DINOSAUR GHOSTS
WHY DO TESTICLES MOVE
WHY ARE THERE PSYCHICS
WHY ARE HATS SO EXPENSIVE
WHY IS THERE CAFFEINE IN MY SHAMPOO
WHY DO YOUR BOOBS HURT
WHY DO IGUANAS DIE
WHY ARE THERE SLAVES IN THE BIBLE
WHY DO TWINS HAVE DIFFERENT FINGERPRINTS
WHY ARE AMERICANS AFRAID OF DRAGONS
WHY IS YKK ON ALL ZIPPERS
WHY IS HTTPS CROSSED OUT IN RED
WHY IS THERE A LINE THROUGH HTTPS
WHY IS THERE A RED LINE THROUGH HTTPS ON FACEBOOK
WHY IS HTTPS IMPORTANT

WHY ARE THERE WEEKS
WHY DO I FEEL DIZZY
WHY AREN'T ECONOMISTS RICH
WHY DO AMERICANS CALL IT SOCCER
WHY ARE MY EARS RINGING
WHY ARE THERE SO MANY AVENGERS
WHY ARE THE AVENGERS FIGHTING THE X MEN
WHY IS WOLVERINE NOT IN THE AVENGERS
WHY ARE THERE SWARMS OF GNATS
WHY IS THERE PHLEGM
WHY IS THERE LAVA
WHY ARE THERE SO MANY CROWS IN ROCHESTER, MN
WHY IS PSYCHIC WEAK TO BUG
WHY DO CHILDREN GET CANCER
WHY IS POSEIDON ANGRY WITH ODYSSEUS
WHY IS THERE ICE IN SPACE
WHY ARE THERE ANTS IN MY LAPTOP
WHY IS EARTH TILTED
WHY IS SPACE BLACK
WHY IS OUTER SPACE SO COLD
WHY ARE THERE PYRAMIDS ON THE MOON
WHY IS NASA SHUTTING DOWN
WHY ARE THERE FEMALE MR MIMES

WHY IS THERE AN OWL IN MY BACKYARD
WHY IS THERE AN OWL OUTSIDE MY WINDOW
WHY IS THERE AN OWL ON THE DOLLAR BILL
WHY DO OWLS ATTACK PEOPLE
WHY ARE AK 47s SO EXPENSIVE
WHY ARE THERE HELICOPTERS CIRCLING MY HOUSE
WHY ARE THERE GODS
WHY ARE THERE TWO SPOCKS
WHY IS MT VESUVIUS THERE
WHY DO THEY SAY T MINUS
WHY ARE THERE OBELISKS
WHY ARE WRESTLERS ALWAYS WET
WHY ARE OCEANS BECOMING MORE ACIDIC
WHY IS ARWEN DYING
WHY AREN'T MY QUAIL LAYING EGGS
WHY AREN'T MY QUAIL EGGS HATCHING
WHY AREN'T THERE ANY FOREIGN MILITARY BASES IN AMERICA
WHY IS THERE HELL IF GOD FORGIVES
WHY IS GPS FREE
WHY IS SEX SO IMPORTANT

WHY IS LIFE SO BORING
WHY ARE MY BOOBS ITCHY
WHY ARE CIGARETTES LEGAL
WHY ARE THERE DUCKS IN MY POOL
WHY IS JESUS WHITE
WHY IS THERE LIQUID IN MY EAR
WHY DO Q TIPS FEEL GOOD
WHY DO GOOD PEOPLE DIE

WHY ARE ULTRASOUNDS IMPORTANT
WHY ARE ULTRASOUND MACHINES EXPENSIVE
WHY IS STEALING WRONG
WHY IS THERE NO KING IN ENGLAND
WHY ARE DOGS AFRAID OF FIREWORKS