SOCIAL COGNITION:

How do children learn to follow gaze, share joint attention, imitate their teachers, and use tools during social interactions?

Stephen Grossberg
steve@bu.edu
http://cns.bu.edu/~steve

BOSTON UNIVERSITY

DARPA SyNAPSE

This lecture sketches aspects of a neural architecture

called CRIB

Circular Reactions for Imitative Behavior

in a recent article of the same title:

Grossberg, S. and Vladusich, T. (2010).
***Neural Networks*, 23, 940-965**

See
http://cns.bu.edu/~steve

Part of a special issue called:

SOCIAL COGNITION: FROM BABIES TO ROBOTS

WHY IS IT POSSIBLE TO MODEL THIS NOW?

It builds on 50 years of model development

Based on a *modeling method* that unifies multiple levels of description:

behavior
neurophysiology
neuroanatomy
biophysics
biochemistry

Mind/Body Problem

by showing how advanced brains achieve
AUTONOMOUS ADAPTATION TO A CHANGING WORLD

2007 IJCNN plenary lecture
http://ewh.ieee.org/cmte/cis/mtsc/ieeecis/tutorial2007/IJCNN07_plenary/IJCNN_plenary_81307.pdf

See link from my web page!

AFTER GOING THROUGH THIS MODELING PROCESS, WHAT'S THE RESULT?!

IS THE BRAIN JUST AN ENDLESS "BAG OF TRICKS"?

V.S. Ramachandran

NO!

TRUE THEORIES ARE EMERGING

A small number of equations

e.g., shunting activation dynamics (STM)
activity-gated learning (LTM)
habituative transmitter gates (MTM) …

A larger number of modules*

e.g., on-center off-surround nets
resonant matching nets
opponent processing nets
spectral timing nets
boundary completion nets
filling-in nets…

Specialized combinations of modules*, using a few basic equations, are assembled in architectures that solve modal problems

A still larger number of modal architectures

e.g. vision
audition
smell
touch
cognition
emotion…

*Modules are microassemblies, not the "independent modules" of AI

WHAT PRINCIPLES DETERMINE HOW MODAL ARCHITECTURES ARE DESIGNED?

ADAPTIVE BEHAVIOR IS ORGANIZED AS

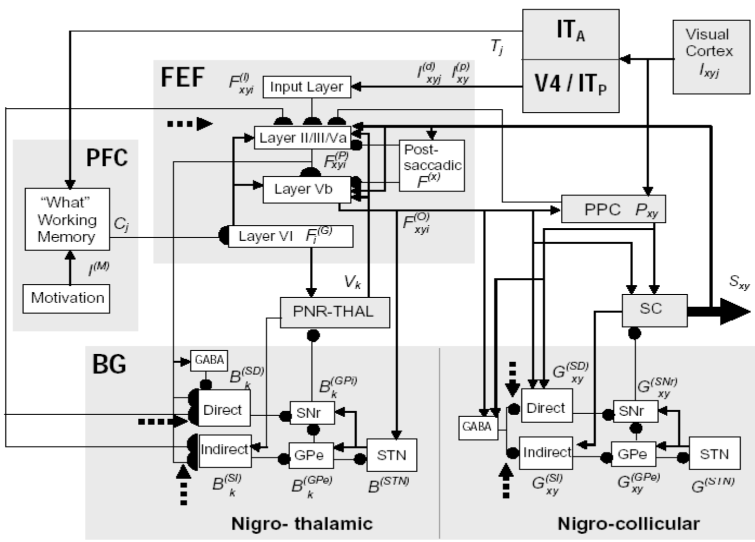
PERCEPTION

COGNITION

EMOTION

ACTION

CYCLES



HOW DOES THE BRAIN COMPUTE

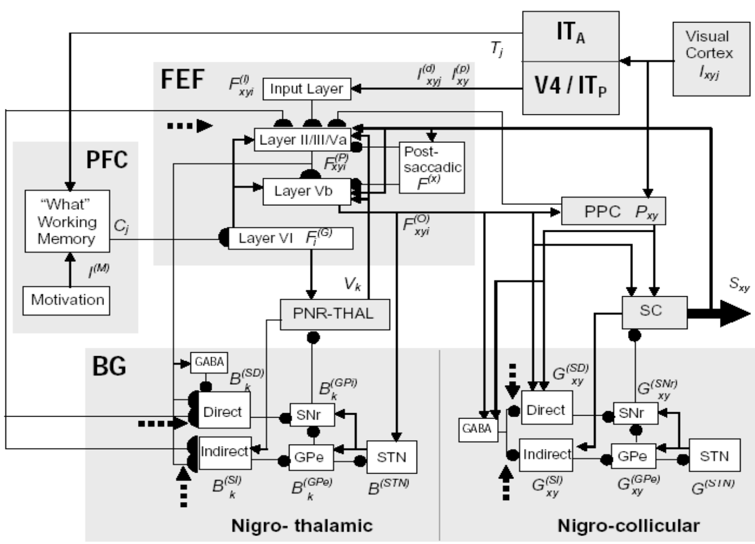
PERCEPTION

COGNITION

EMOTION

ACTION

SYSTEMS?



How is brain computation organized?

This is clarified by:

NEW PARADIGMS for brain computing

INDEPENDENT MODULES
Computer Metaphor

COMPLEMENTARY COMPUTING
What is the nature of brain specialization?

LAMINAR COMPUTING
Why are all neocortical circuits organized in layers?
How do laminar circuits give rise to biological intelligence?

NEW PARADIGMS for brain computing

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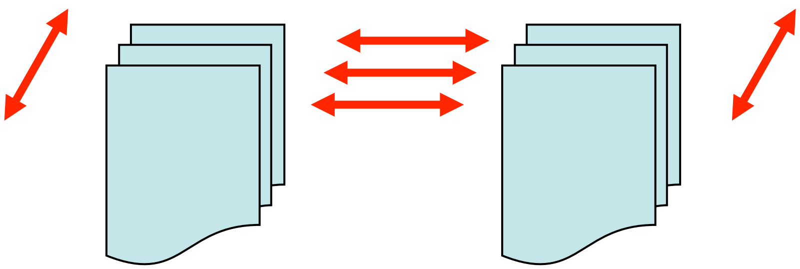
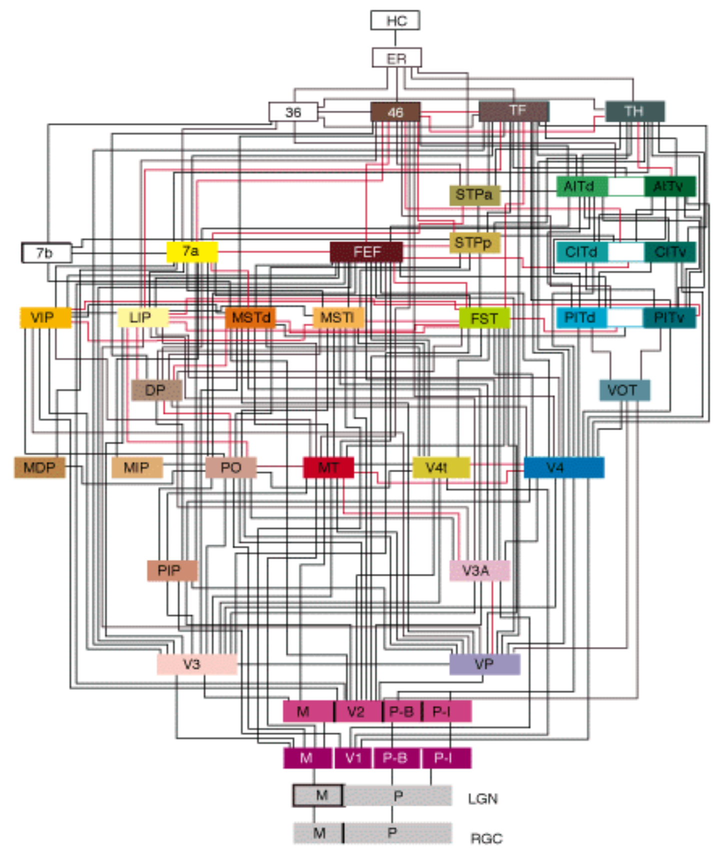
COMPLEMENTARY COMPUTING

New principles of UNCERTAINTY and COMPLEMENTARITY clarify why

Multiple Parallel Processing Streams Exist in the Brain





WHAT ARE COMPLEMENTARY PROPERTIES?

Analogies:
Lock and key, puzzle pieces fitting together

Computing one set of properties at a processing stage prevents that stage from computing a complementary set of properties

Complementary parallel processing streams are BALANCED against one another

INTERACTIONS between streams overcomes their complementary weaknesses and support intelligent and creative behaviors

SOME COMPLEMENTARY PROCESSES

Visual Boundary **Interbob Stream V1-V4**	**Visual Surface** **Blob Stream V1-V4**
Visual Boundary **Interbob Stream V1-V4**	**Visual Motion** **Magno Stream V1-MT**
WHAT Steam **Perception & Recognition** **Inferotemporal and** **Prefrontal areas**	**WHERE Stream** **Space & Action** **Parietal and** **Prefrontal areas**
Object Tracking **MT Interbands and MSTv**	**Optic Flow Navigation** **MT Bands and MSTd**
Motor Target Position **Motor and Parietal Cortex**	**Volitional Speed** **Basal Ganglia**

SOME COMPLEMENTARY PROCESSES

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BUILDING COMPLETE VISUAL PERCEPTION, COGNITION, EMOTION, ACTION SYSTEMS

Child's task:
Visually find and pick up a stationary cup of milk to drink

Spatially orient to the cup	**Where stream**
See cup	**What stream**
Recognize cup	**What stream**
Want to pick cup up	**What stream**
Plan to pick cup up	**What-Where stream**
Pick cup up	**What-Where stream**

This perception-cognition-emotion-action cycle uses What-Where learned information fusion

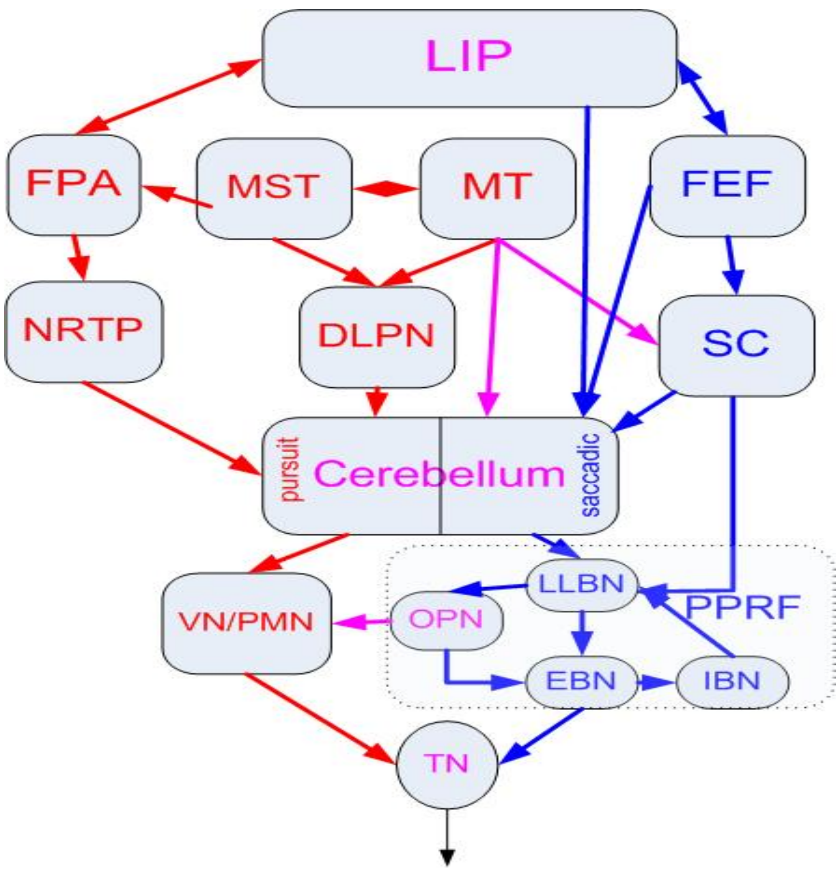
Need visual, temporal, parietal, prefrontal cortices...

MODELS FOR A CHILD TO VISUALLY FIND AND PICK UP A STATIONARY CUP OF MILK TO DRINK

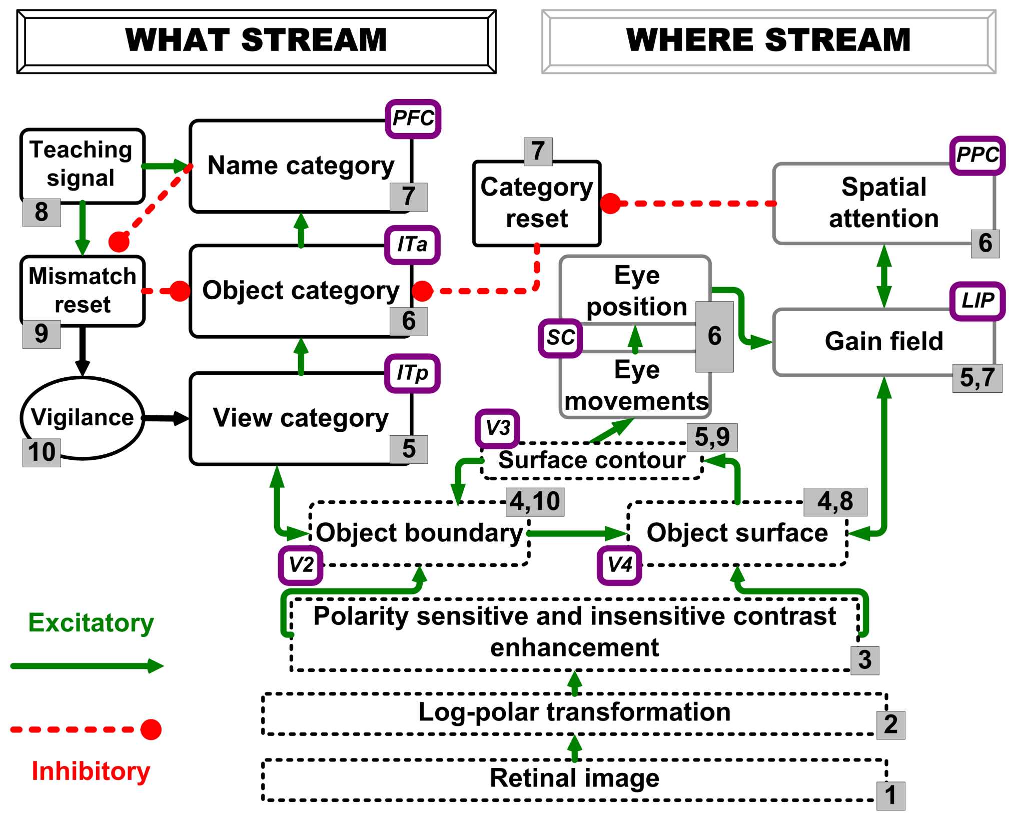
Spatially Orient to the Cup

Bullock, *Grossberg*, Hasselmo, *Mingolla*

Berzhanskaya, Browning, Elder, *Fazl*, Gnadt, Gorchetchnikov, Huang, Pilly, *Srihasam*, Zilli



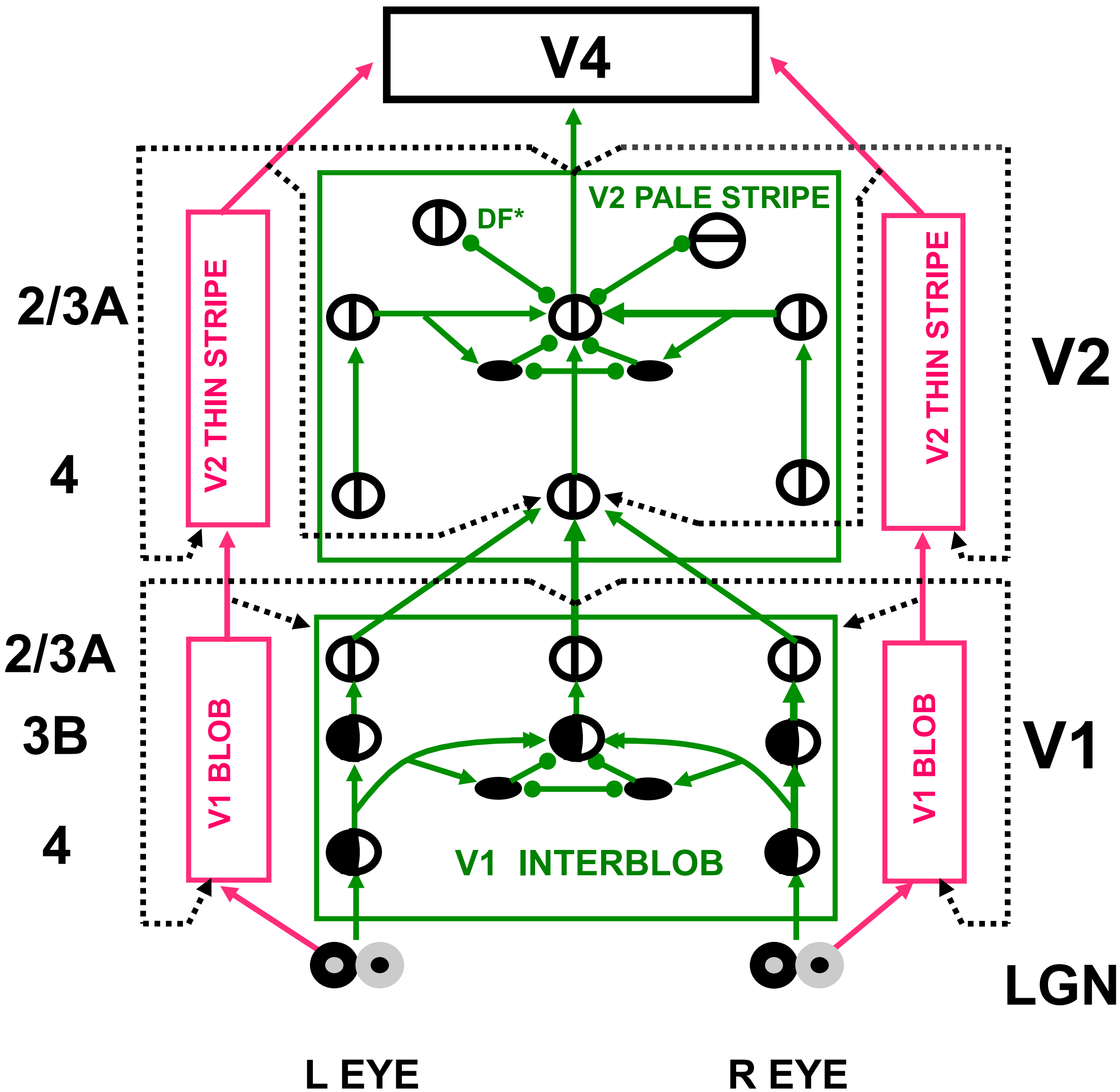
J. Cognitive Neuroscience, 2009, 2011



Cognitive Psychology, 2009

MODELS FOR A CHILD TO VISUALLY FIND AND PICK UP A STATIONARY CUP OF MILK TO DRINK

See Cup



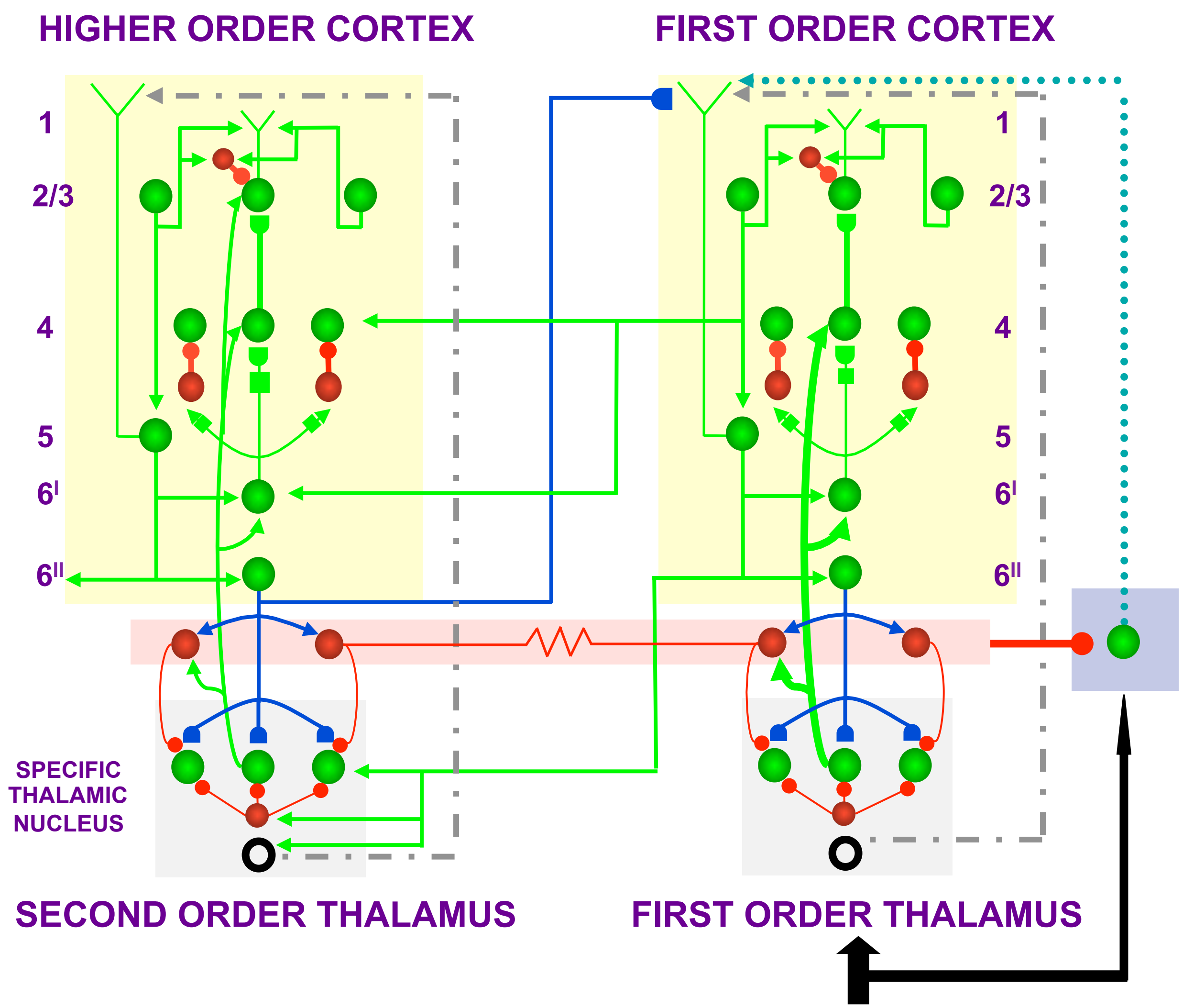
Carpenter, *Grossberg*, Mingolla, Watanabe

Bhatt, *Cao*, Chelian, Fazl, *Fang*, Foley, Hong, Huang, Kuhlmann, Sai, *Yazdanbakhsh*

Vision Research, 2005
Spatial Vision, 2005
Vision Research, 2007
Vision Research, 2008

MODELS FOR A CHILD TO VISUALLY FIND AND PICK UP A STATIONARY CUP OF MILK TO DRINK

Recognize Cup



Carpenter, *Grossberg*
Amis, Bhatt, Chelian, Ersoy, Fazl, Gnadt, Huang, Leveille, Ogas, Olivera, *Versace*, Woods

Brain Research, 2008

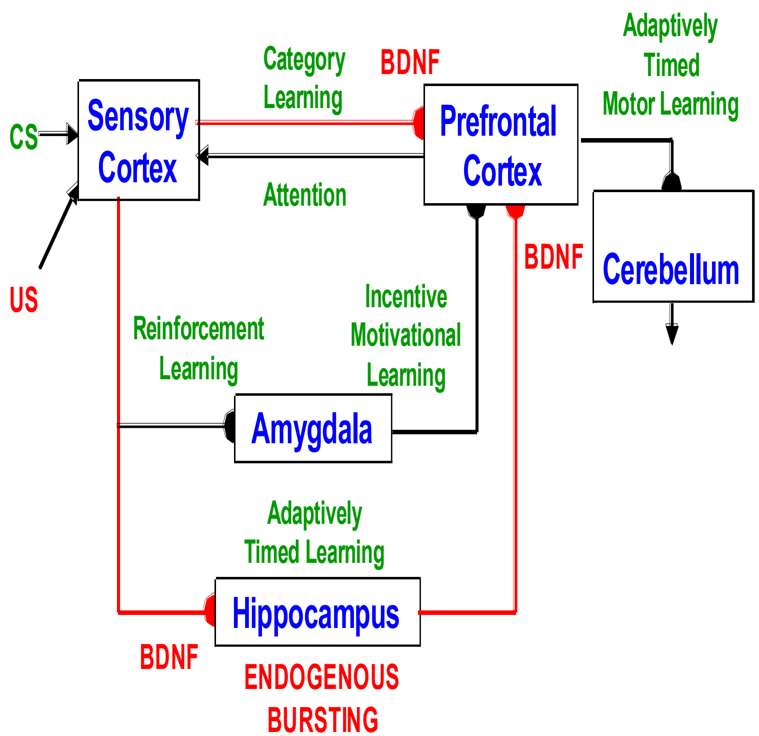
LAMINAR COMPUTING!

MODELS FOR A CHILD TO VISUALLY FIND AND PICK UP A STATIONARY CUP OF MILK TO DRINK

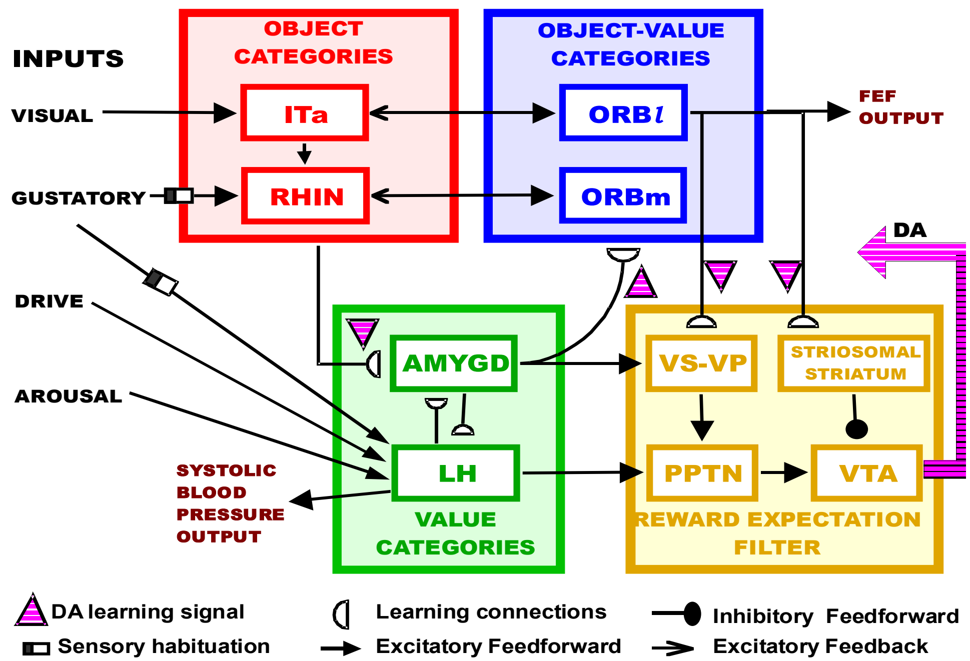
Want to Pick Cup Up

Bullock, Grossberg

Anderson, *Dranias, Franklin,* Gnadt, *Seidman*



In preparation

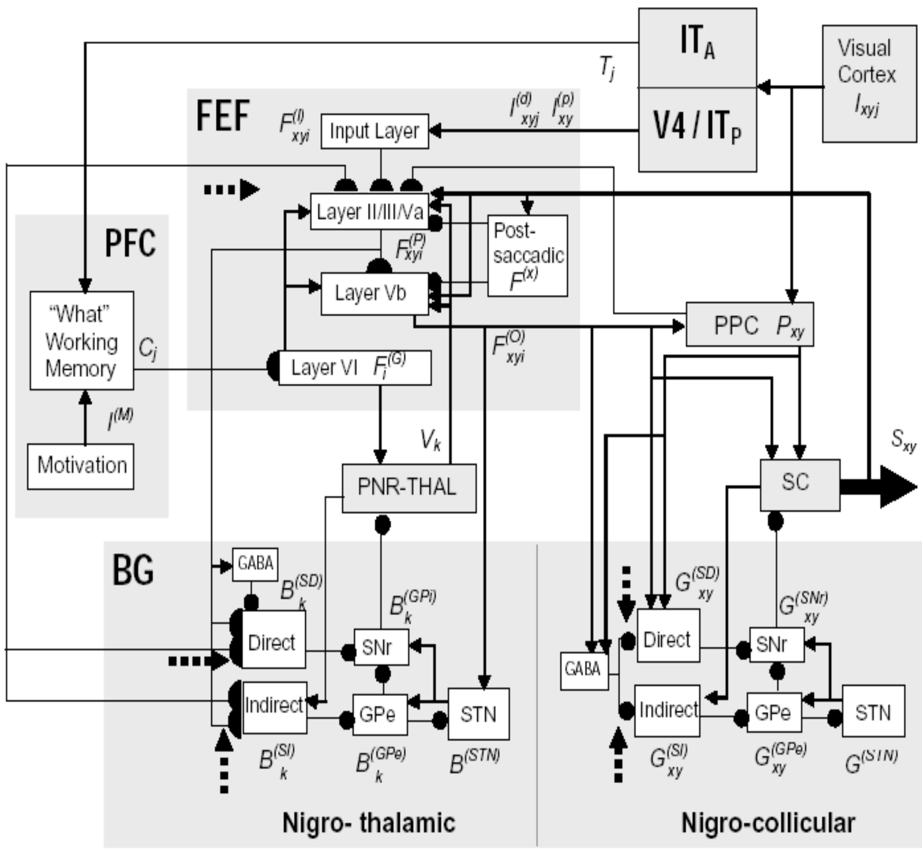


Behavioral Neuroscience, 2008
Brain Research, 2008

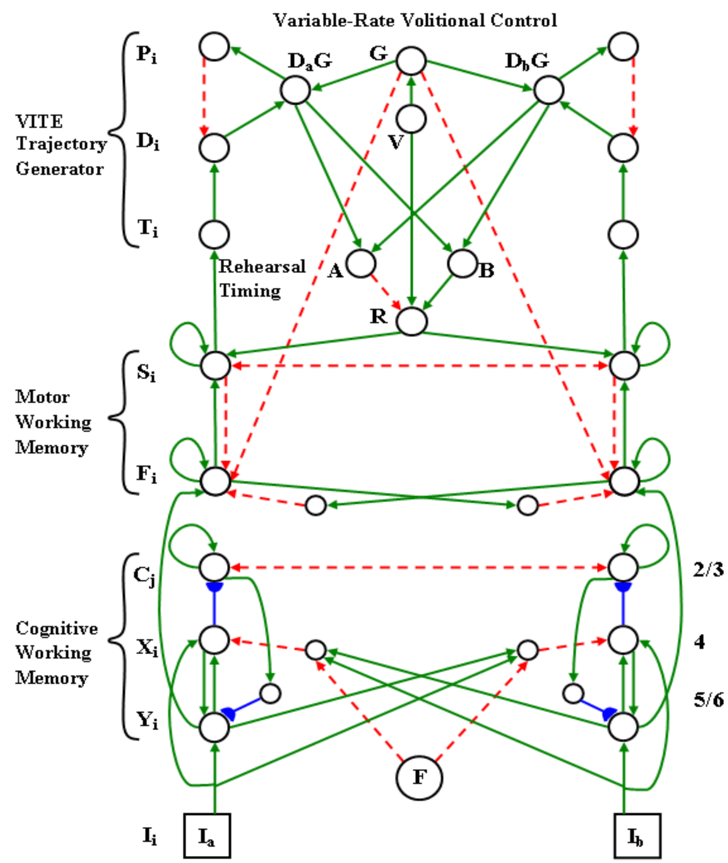
MODELS FOR A CHILD TO VISUALLY FIND AND PICK UP A STATIONARY CUP OF MILK TO DRINK

Plan to Pick Cup Up

Bullock, *Grossberg*, Hasselmo,
Anderson, Gnadt, Ivey, Kazerounian, *Pearson*, *Pilly*, Silver, *Tan*, Zilli



Neural Networks, 2004
Neuroscience Letters, 2008
Vision Research, 2008



Psychological Review, 2008

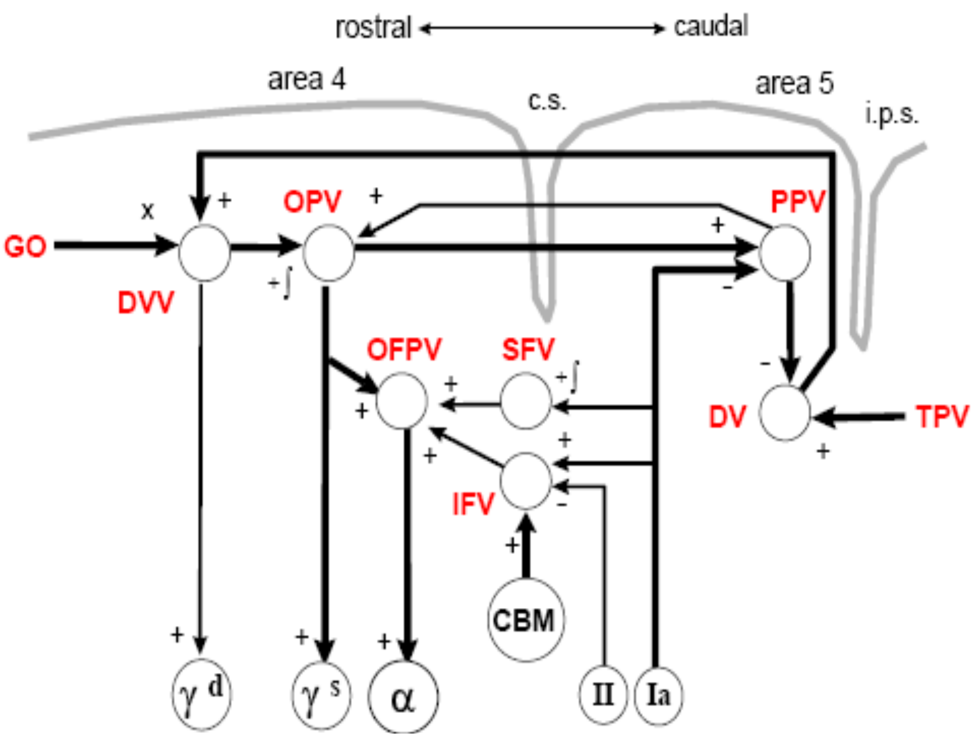
LAMINAR COMPUTING!

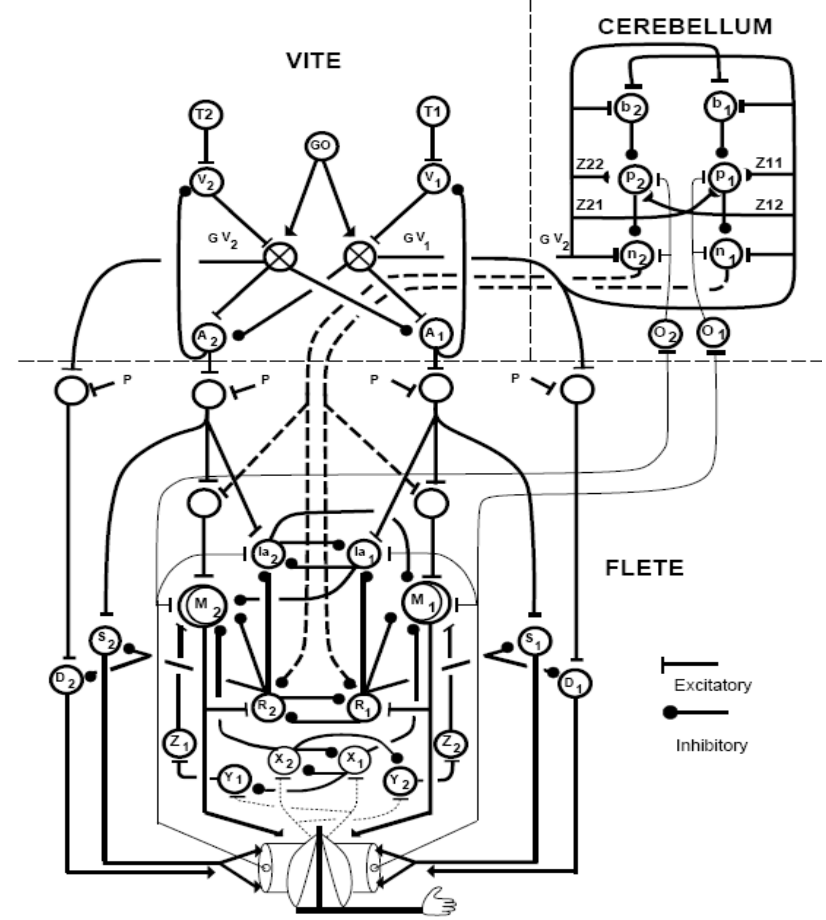
MODELS FOR A CHILD TO VISUALLY FIND AND PICK UP A STATIONARY CUP OF MILK TO DRINK

Pick Cup Up

Bullock, ***Grossberg***, **Guenther**

Pearson, (*Cisek*, *Contreras-Vidal*, Dessing, Mannes, Paine, Peper, Rhodes, Ulloa)





Cerebral Cortex, 1998
J. Cognitive Neuroscience, 1998

Learning and Memory, 1997

NOT ENOUGH FOR SOCIAL COGNITION!

TWO MAJOR KINDS OF THEMES TODAY

I. What is an
INTRA-PERSONAL CIRCULAR REACTION?

What is an
INTER-PERSONAL CIRCULAR REACTION

How does the latter build upon the former
to bridge the gap between student and teacher?

2. How does a student learn to imitate
a teacher who sees the world from a different perspective?

What “glue” binds the two perspectives together?

NOT ENOUGH, THOUGH, FOR SOCIAL COGNITION!

TWO MAJOR KINDS OF THEMES TODAY

I. What is an
INTRA-PERSONAL CIRCULAR REACTION?

What is an
INTER-PERSONAL CIRCULAR REACTION

How does the latter build upon a student's
own learning to bridge the gap
between student and teacher

2. How does a student learn to imitate
a teacher who sees the world from a different perspective?

What "glue" binds the two perspectives together?

WHAT IS A
INTRA-PERSONAL CIRCULAR REACTION?

Piaget, 1945, 1951, 1952

REACHING

Baby endogenously babbles arm movements

Its eyes reactively track its moving hand

It learns associations from hand position to eye position
AND from eye position to hand position

Then it can volitionally reach where its eyes are looking

DIRECT model

Bullock, Grossberg, & Guenther 1993, J. Cognitive Neuroscience

learns by circular reaction

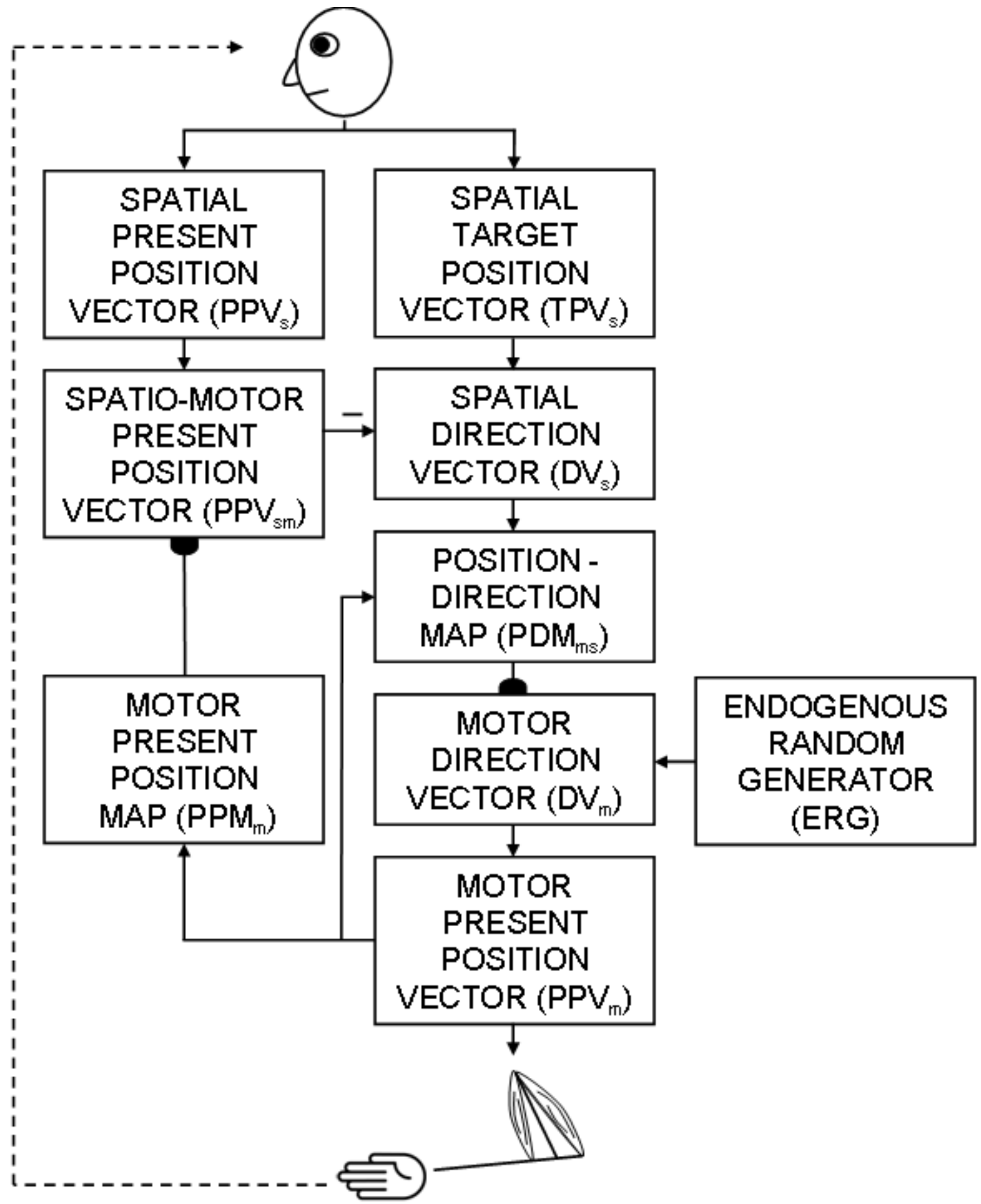
learns spatial representation to mediate between vision and action

motor-equivalent reaching

can reach target with clamped joints

can reach target with a TOOL on the first try under visual guidance

HOW DID TOOL USE ARISE?!



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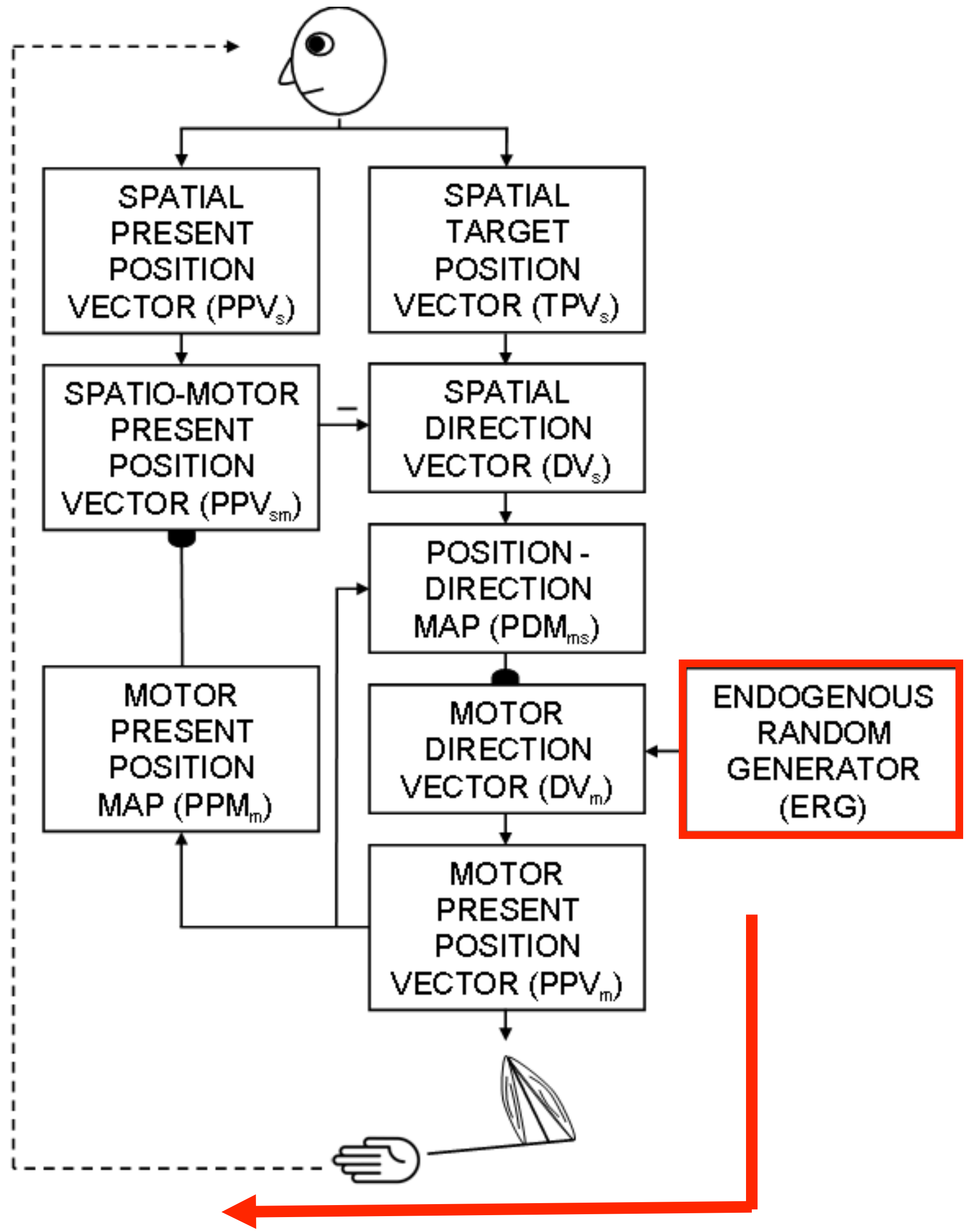

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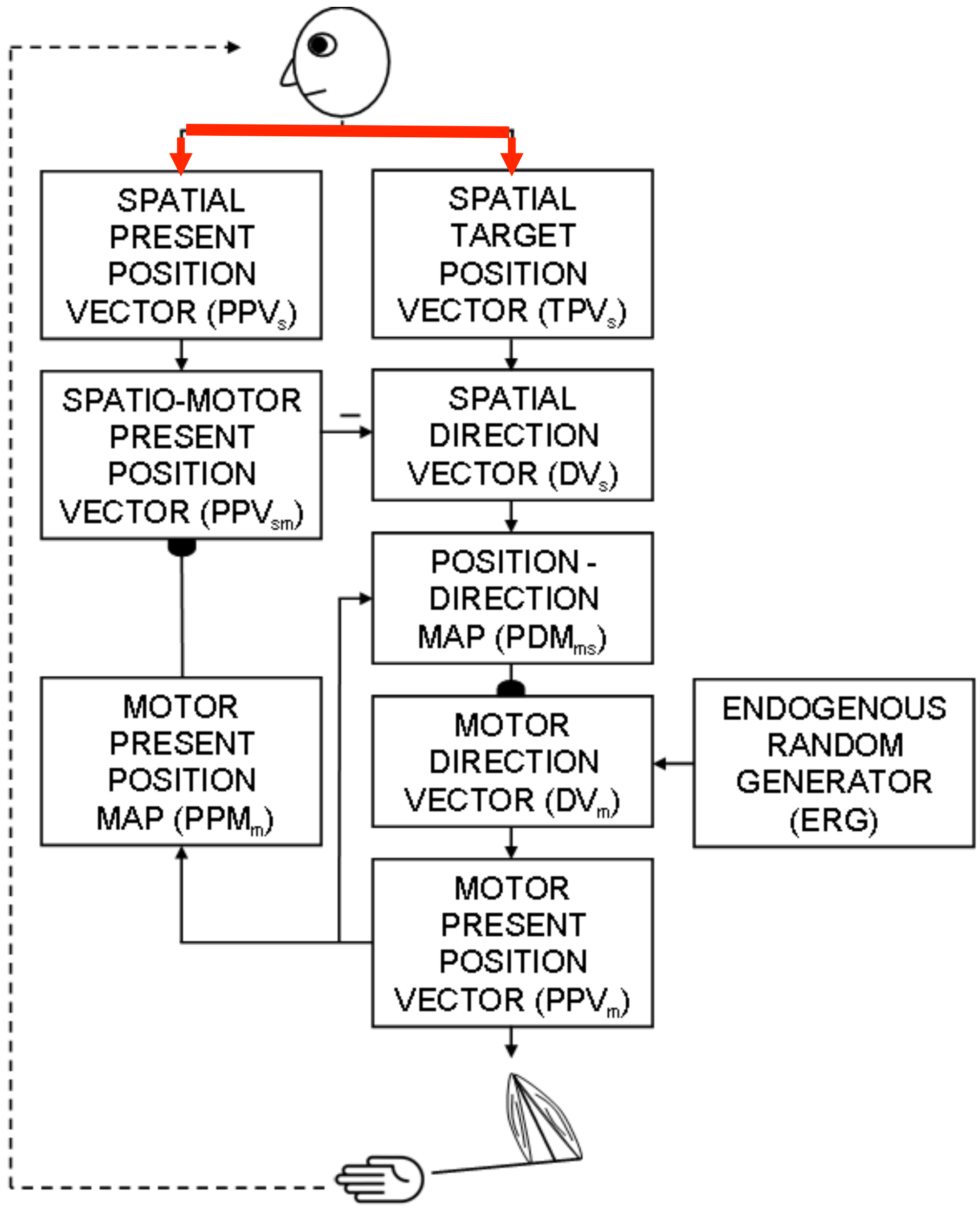

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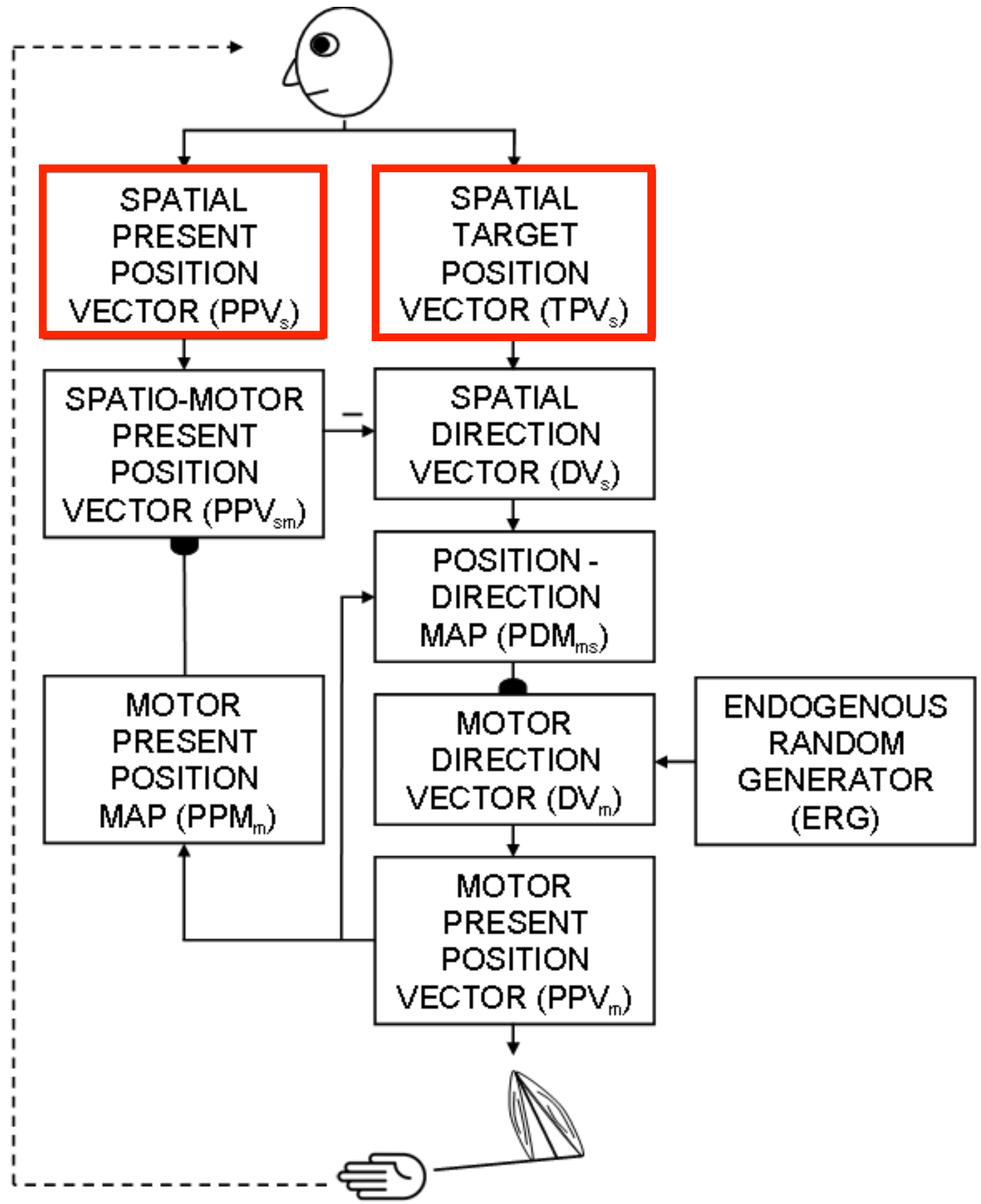

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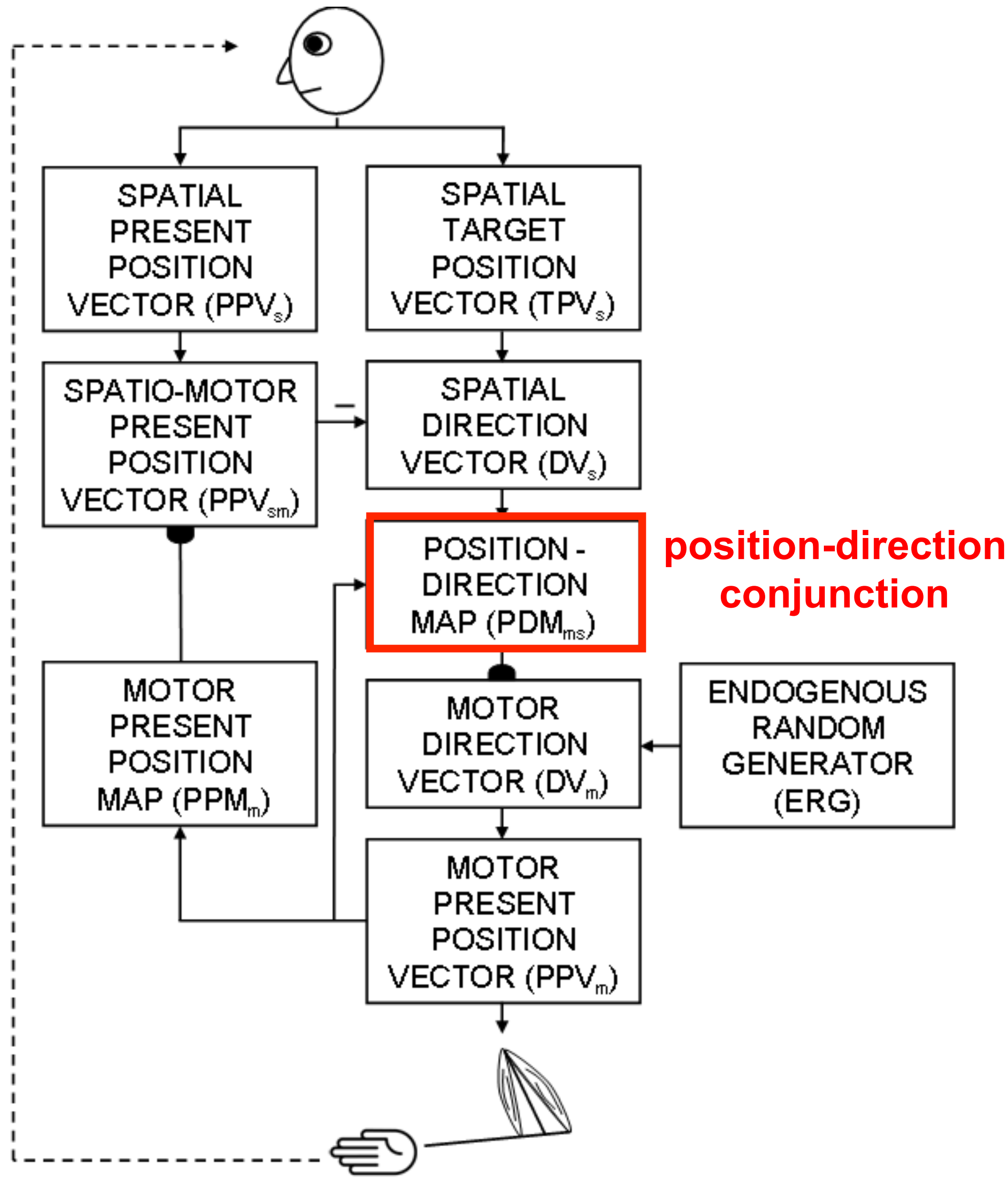

TOOL USE, IMITATION, AND CULTURE

TOOL USE is a necessary step in the development of human societies

DIRECT suggests how the ability (or "affordance") to move a tool in space arose from an INTRA-personal circular reaction whereby a child learns to reach a goal object with either hand in a motor-equivalent way;
i.e., learned a SPATIAL representation that mediates between vision and volitional action

When an animal accidentally discovered how to move a tool in space, how did other animals learn to imitate that skill?

Need JOINT ATTENTION and an INTER-personal circular reaction for rapid cultural propagation of this skill!

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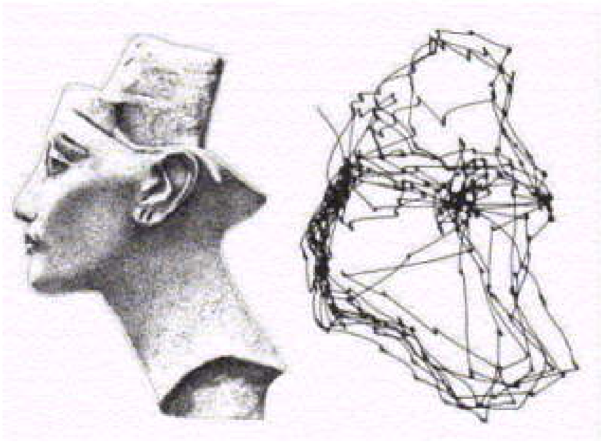
THE ‘GLUE”

from an INTRA-PERSONAL perspective

How does a learner bind multiple views of an object into
a view-invariant object category
during free viewing conditions with eye movements?



Yarbus (1961)

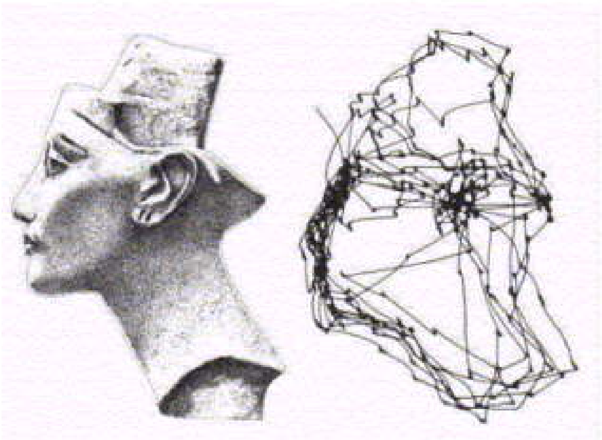
How do the eyes restrict their movements to
different views of an object, even before the
brain knows what the object is?

Why are not all successive eye movements pointed to
random positions in the world?

A BASIC QUESTION FOR INTRA-PERSONAL STABILITY

What is an object?

Invariant object category learning under free viewing conditions



Yarbus (1961)

The intra-personal "glue" is:

SPATIAL ATTENTION

SURFACE-SHROUD RESONANCE

coordinates invariant object category learning

via

What-Where stream interactions

A SERIES OF ARTICLES ABOUT THIS SINCE 2009

Grossberg, S. (2009). Cortical and subcortical predictive dynamics and learning during perception, cognition, emotion, and action. *Philosophical Transactions of the Royal Society of London*, 364, 1223-1234.

Fazl, A., Grossberg, S., and Mingolla, E. (2009). View-invariant object category learning, recognition, and search: How spatial and object attention are coordinated using surface-based attentional shrouds. *Cognitive Psychology*, 58, 1-48.

Cao, Y., Grossberg, S., and Markowitz, J. (2011). How does the brain rapidly learn and reorganize view- and positionally-invariant object representations in inferior temporal cortex? *Neural Networks*, in press.

Foley, N., Grossberg, S., and Mingolla, E. (2011). Neural dynamics of object-based multifocal visual spatial attention and priming: Object cueing, useful-field-of-view, and crowding. Submitted for publication.

THE ‘GLUE”: from Intra-personal to Inter-personal

Can learn to recognize a teacher’s face in any pose (invariance)
and also in a particular pose relative to the learner
…in particular, recognize how teacher’s eyes look
when her face is staring at a particular position in space
Learn invariant categories and position-view categories

Suppose teacher turns her face to put an object down
or pick it up while looking at it

When teacher turns her face, spatial attention can be attracted
to her face: Motion attracts attention!

Spatial attention can flow from teacher’s facial pose
to the moving position of her hand

This spatial attentional locus attracts the learner’s eyes to
to look at the position of the teacher’s hand

An association can then be learned between the teacher’s facial pose
and the position in space where she is looking:
JOINT ATTENTION!

Then a learner’s hand can reach to that position, with or without a TOOL
INTER-PERSONAL CIRCULAR REACTION!

LOTS OF TECHNICAL PROBLEMS NEED TO BE SOLVED

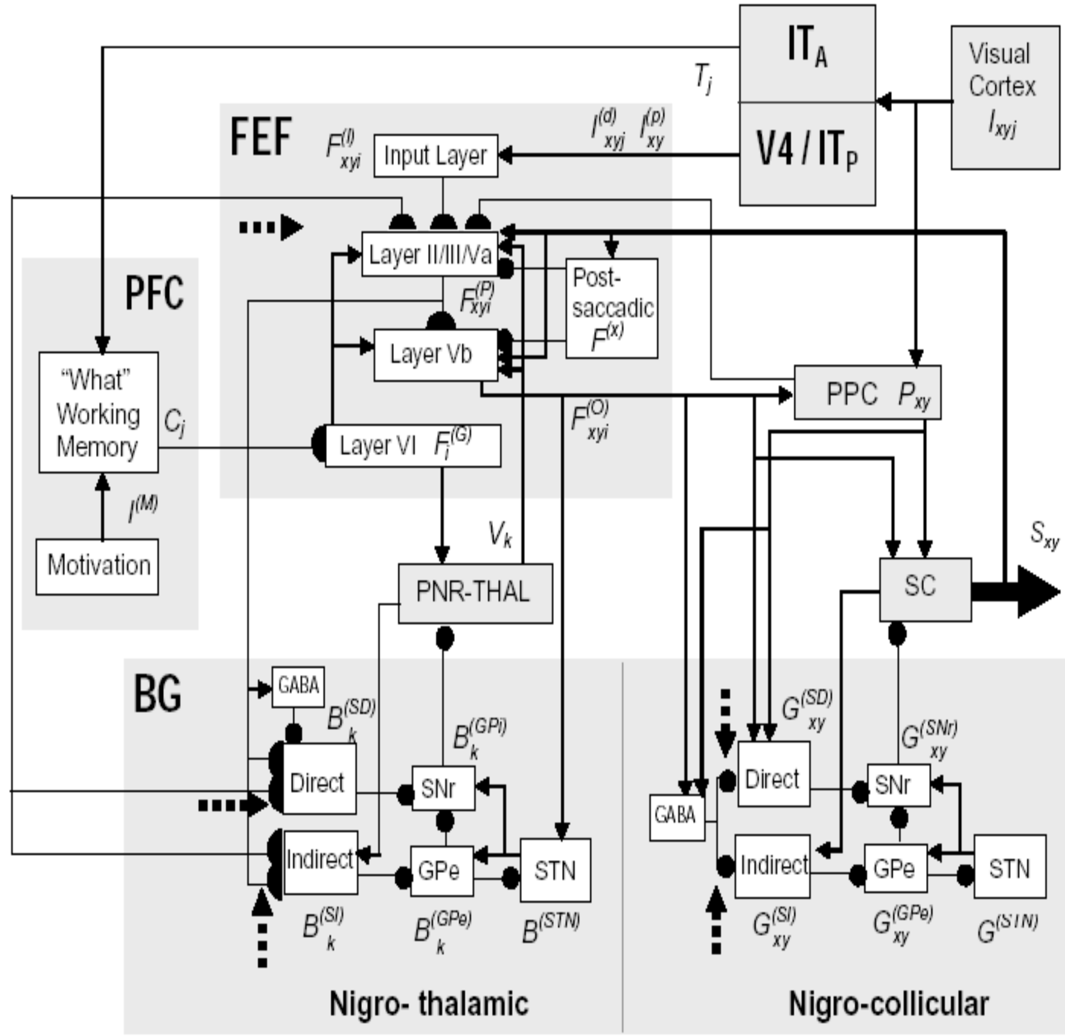
Previous models provide key mechanisms

e.g., JOINT ATTENTION: How is a position-view category of where the teacher looks associated with an eye movement to that position in space?

TELOS model

Brown, Bullock, & Grossberg, 1999, 2004

How basal ganglia and prefrontal cortex interact with inferotemporal cortex and parietal cortex to control learning and performance of saccadic eye movements



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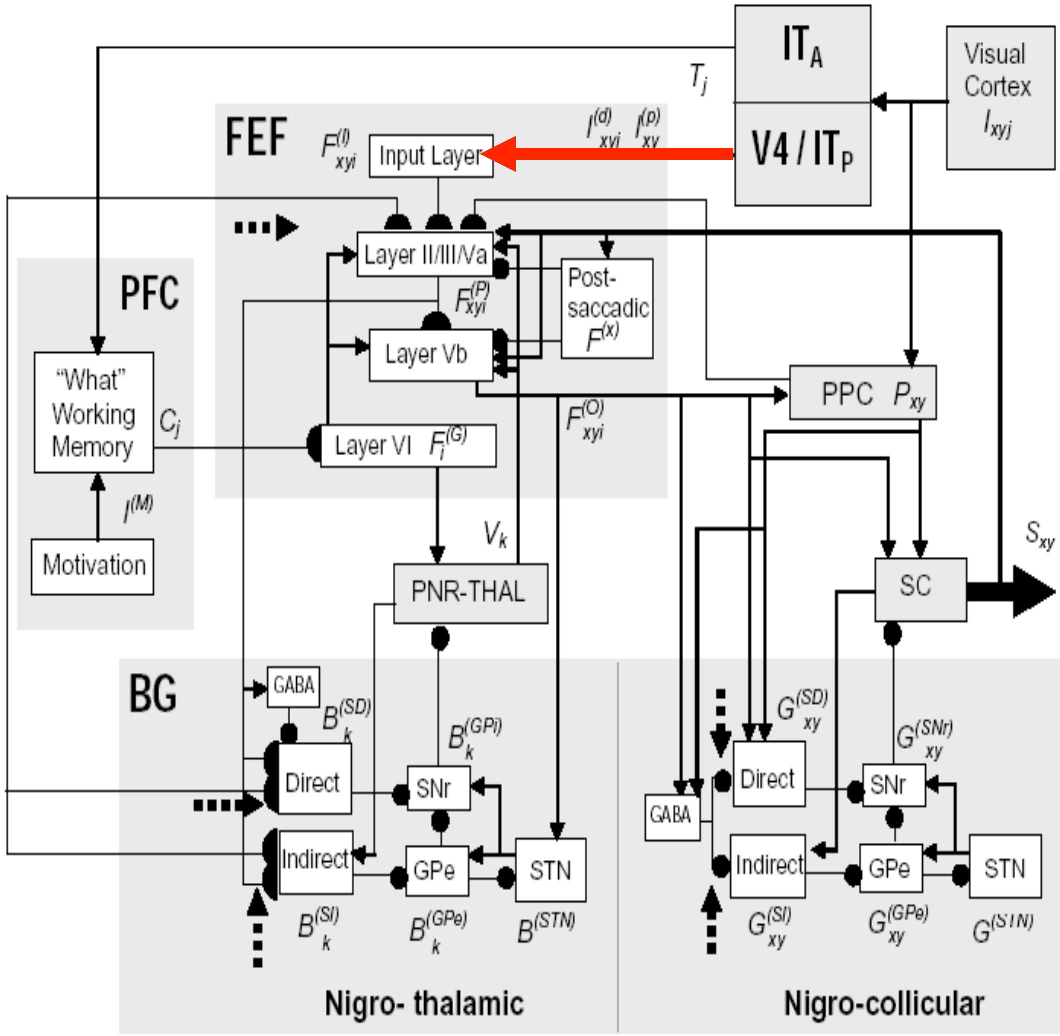
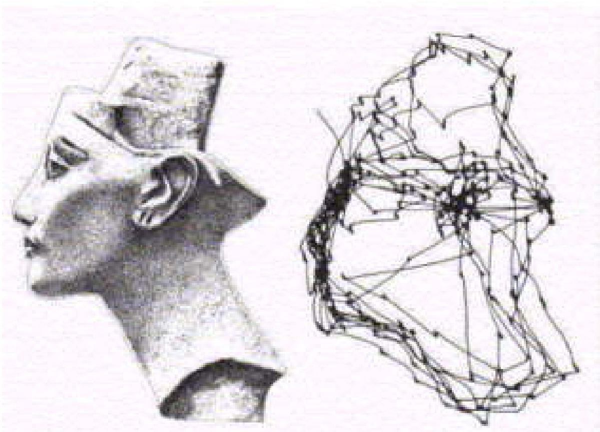


A BASIC QUESTION FOR INTRA-PERSONAL STABILITY

What is an object?

How does the brain learn to bind multiple views of an object into a view-invariant object category while scanning its salient parts with eye movements?



Yarbus (1961)

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SURFACE-SHROUD RESONANCE

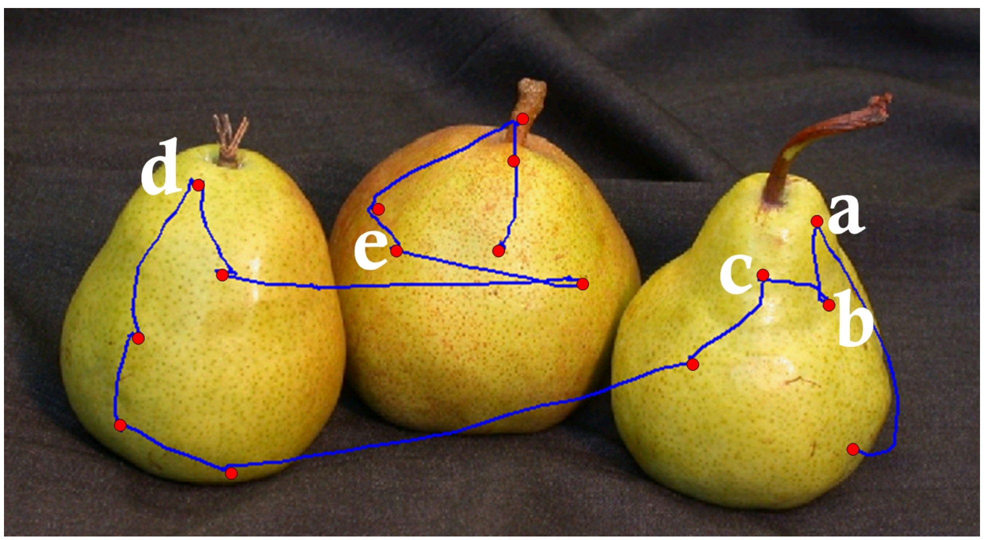
coordinates invariant object category learning

via

What-Where stream interactions

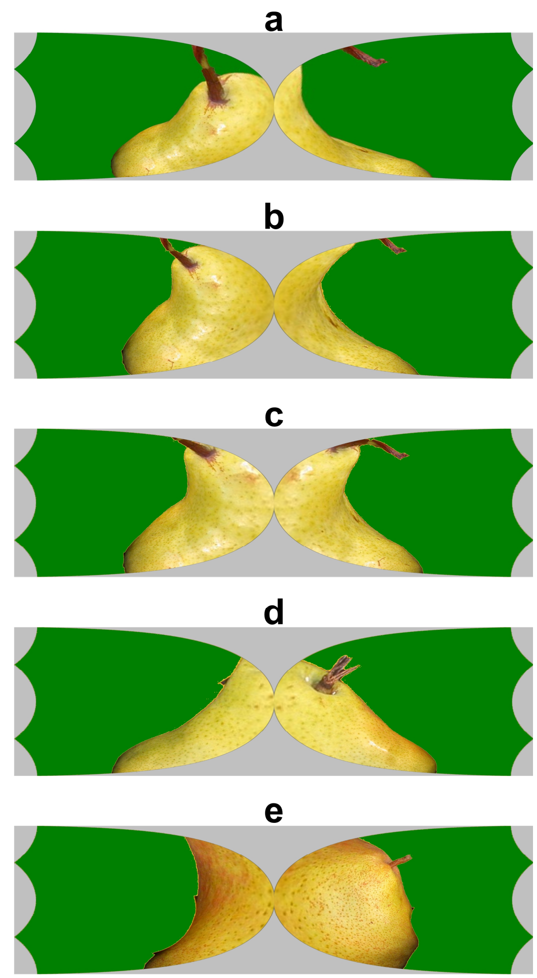
VIEW-INVARIANT OBJECT LEARNING AND RECOGNITION

During unsupervised scanning and learning about the world, no one tells the brain what views belong to which objects while it learns view-invariant object categories



Three pears: Anjou, Bartlett, Comice
Which is the Bartlett pear?

Cortical magnification in V1

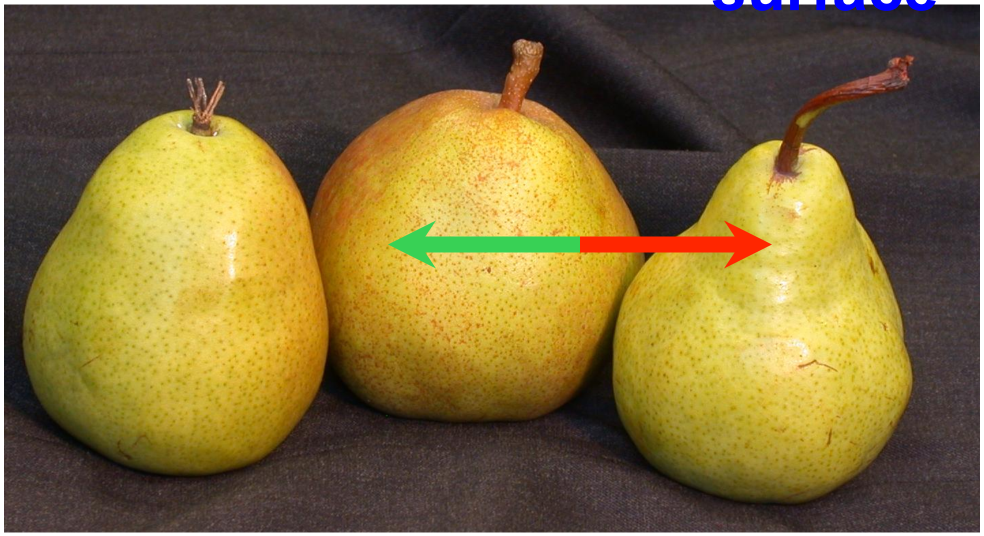


EYE MOVEMENTS, SURFACES, AND LEARNING

The brain must somehow

LEARN
when eyes move
ON the same surface

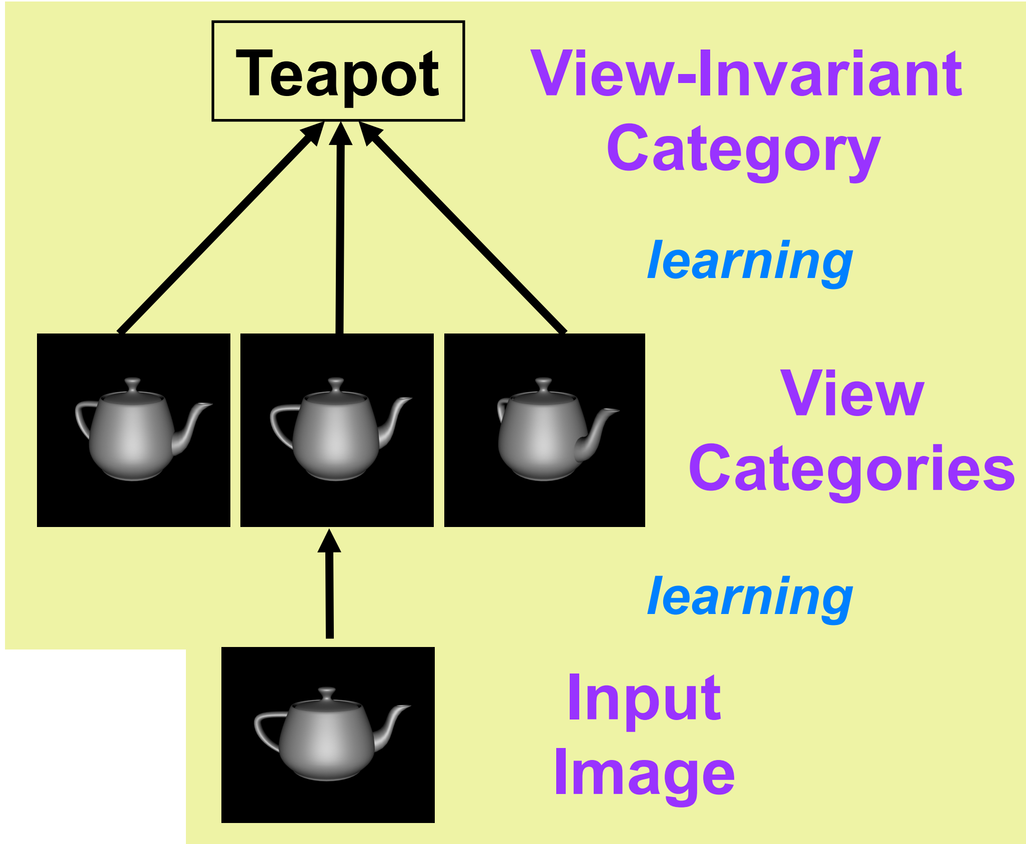
STOP LEARNING
when eyes move
OFF that
surface



HOW IS AN INFINITE REGRESS PREVENTED?

PROPOSED SOLUTION:

A *pre-attentively* formed SURFACE REPRESENTATION (e.g., in V4) activates an ATTENTIONAL SHROUD in the SPATIAL ATTENTION system (e.g., PPC)



An active shroud inhibits reset of an emerging VIEW-INVARIANT OBJECT CATEGORY as it is associated with multiple learned VIEW CATEGORIES of the surface that are reset as the eyes move

WHAT IS AN ATTENTIONAL SHROUD?

Surface-fitting spatial attention
ATTENTIONAL SHROUD!
marks the object-hood of the
as-yet-undefined object category

Tyler and Kontsevich (1995)
used shrouds to study
perceptual transparency

Cf. Cavanagh, Pylyshyn, Yantis,…

Magritte (1928)

PREDICTION:
Shrouds enable learning of view-invariant object categories

Fazl, A., Grossberg, S., & Mingolla, E. (2009)
View-invariant object category learning, recognition, and search:
How spatial and object attention
are coordinated using surface-based attentional shrouds
Cognitive Psychology

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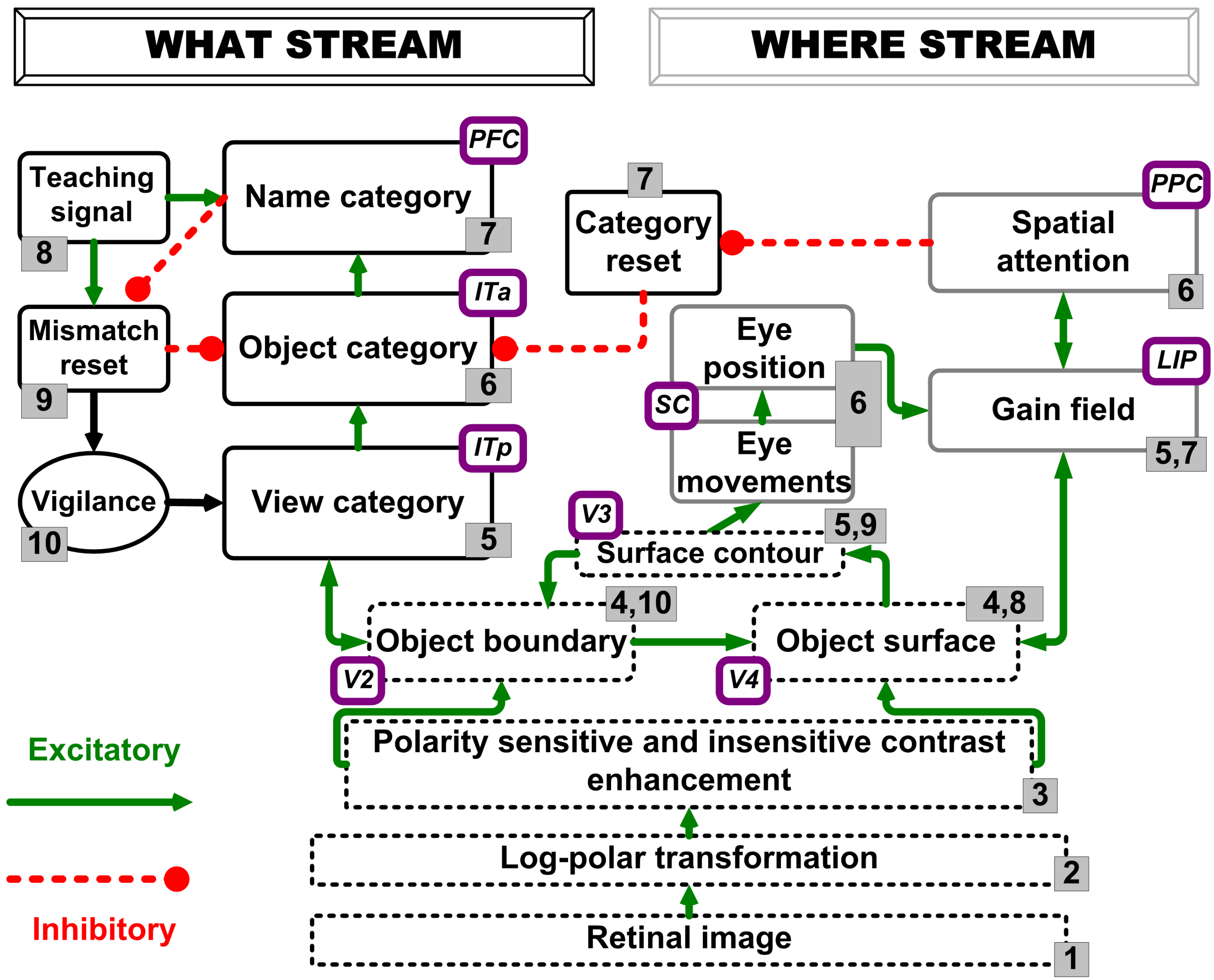
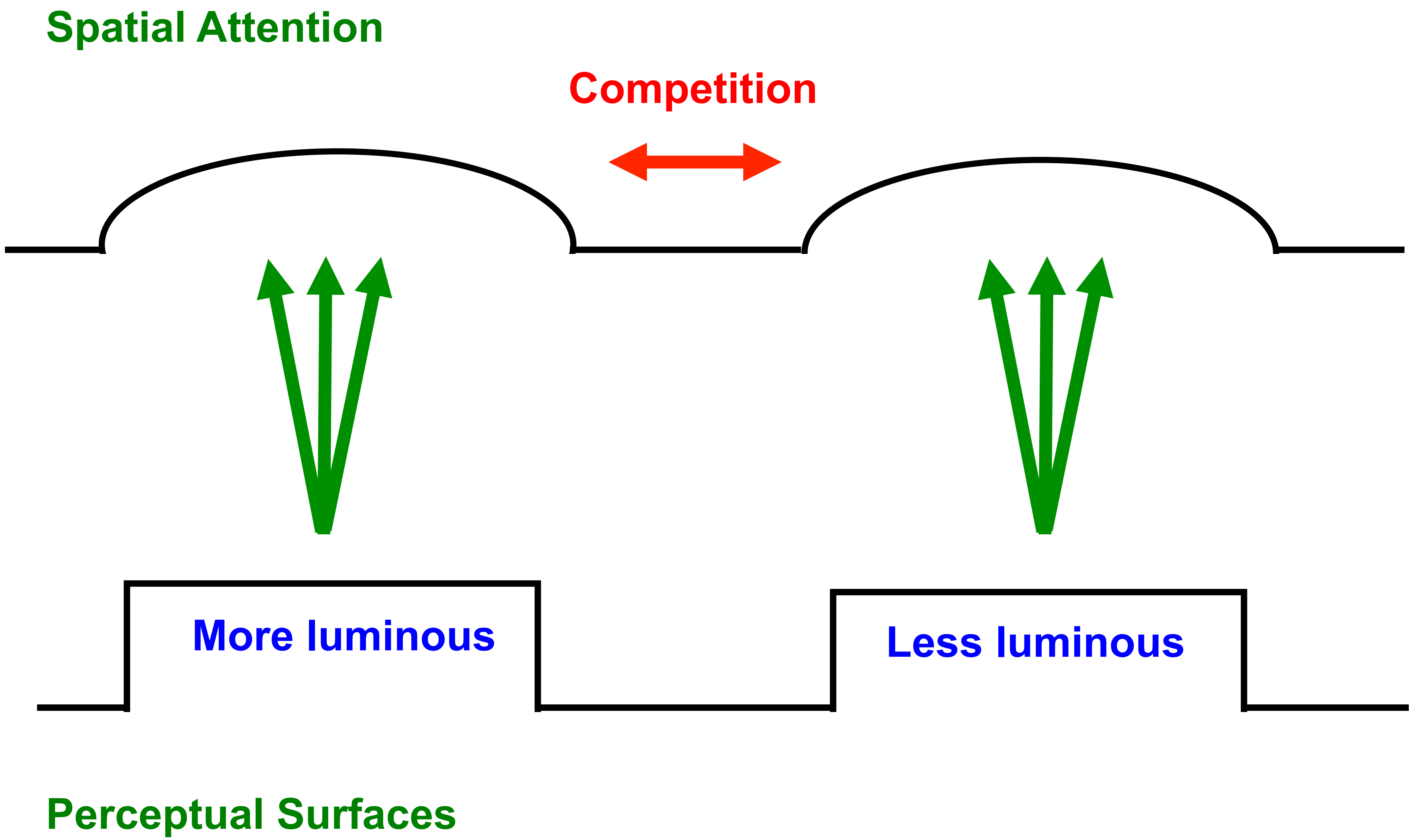
Cognitive Psychology

ARTSCAN model

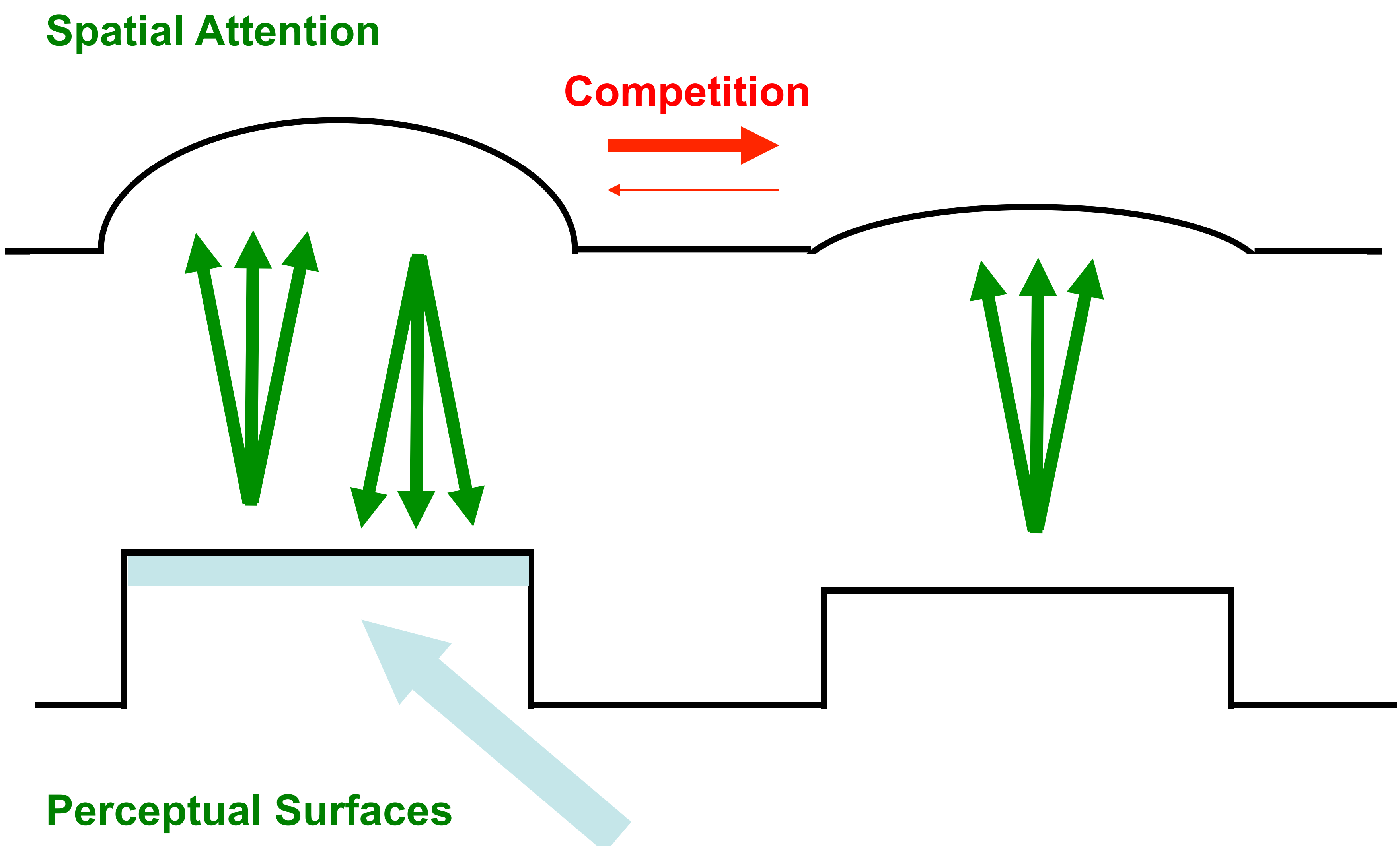
Cortical areas V1, V2, V3A, V4, ITp, ITa, PPC, LIP, PFC



BOTTOM-UP SPATIAL ATTENTIONAL COMPETITION

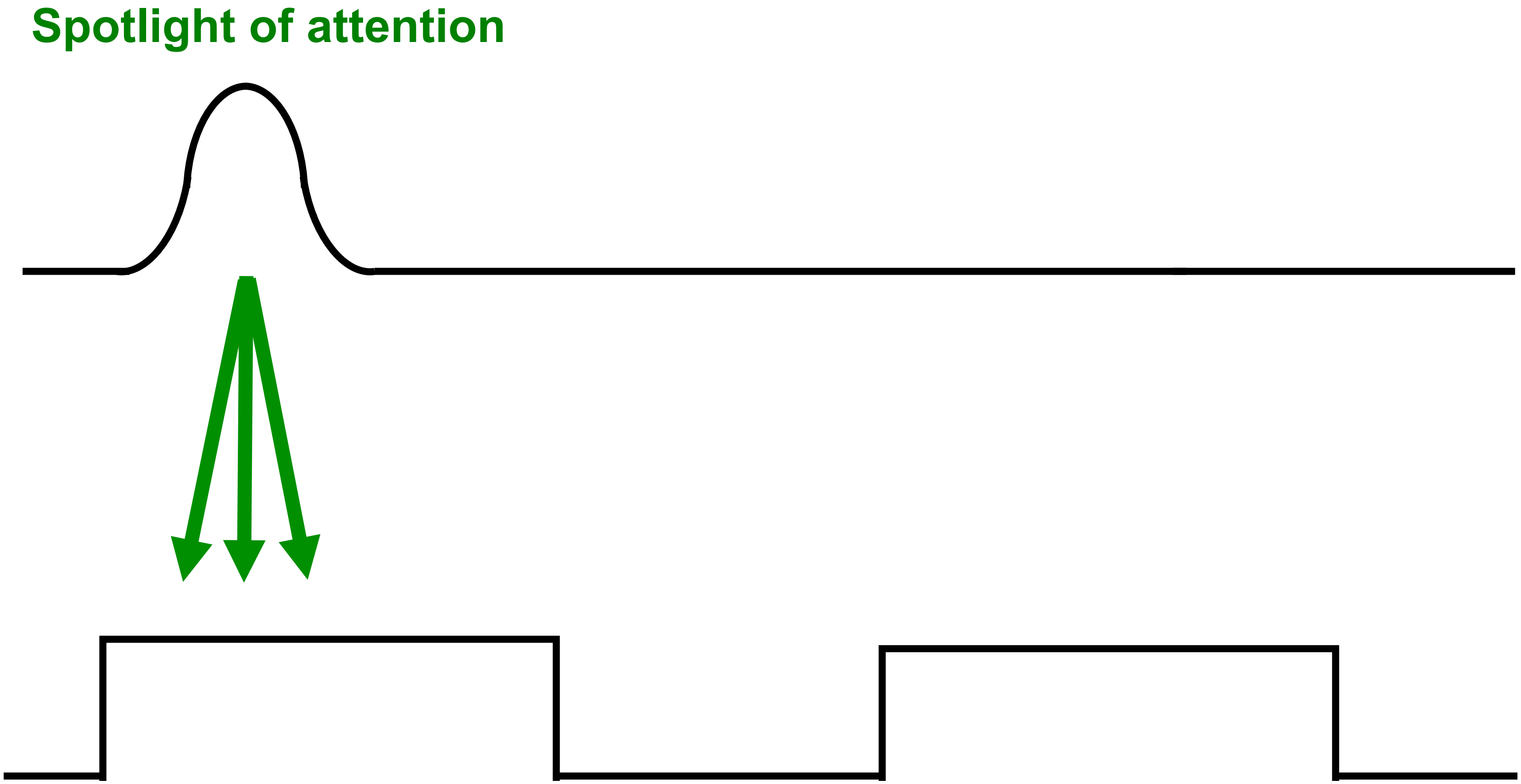


SURFACE-SHROUD RESONANCE



Carrasco, Penpeci-Talgar, & Eckstein (2000)
Reynolds & Desimone (2003)

RECONCILING SPOTLIGHTS AND SHROUDS:
TOP-DOWN ATTENTIONAL SPOTLIGHT BECOMES A SHROUD



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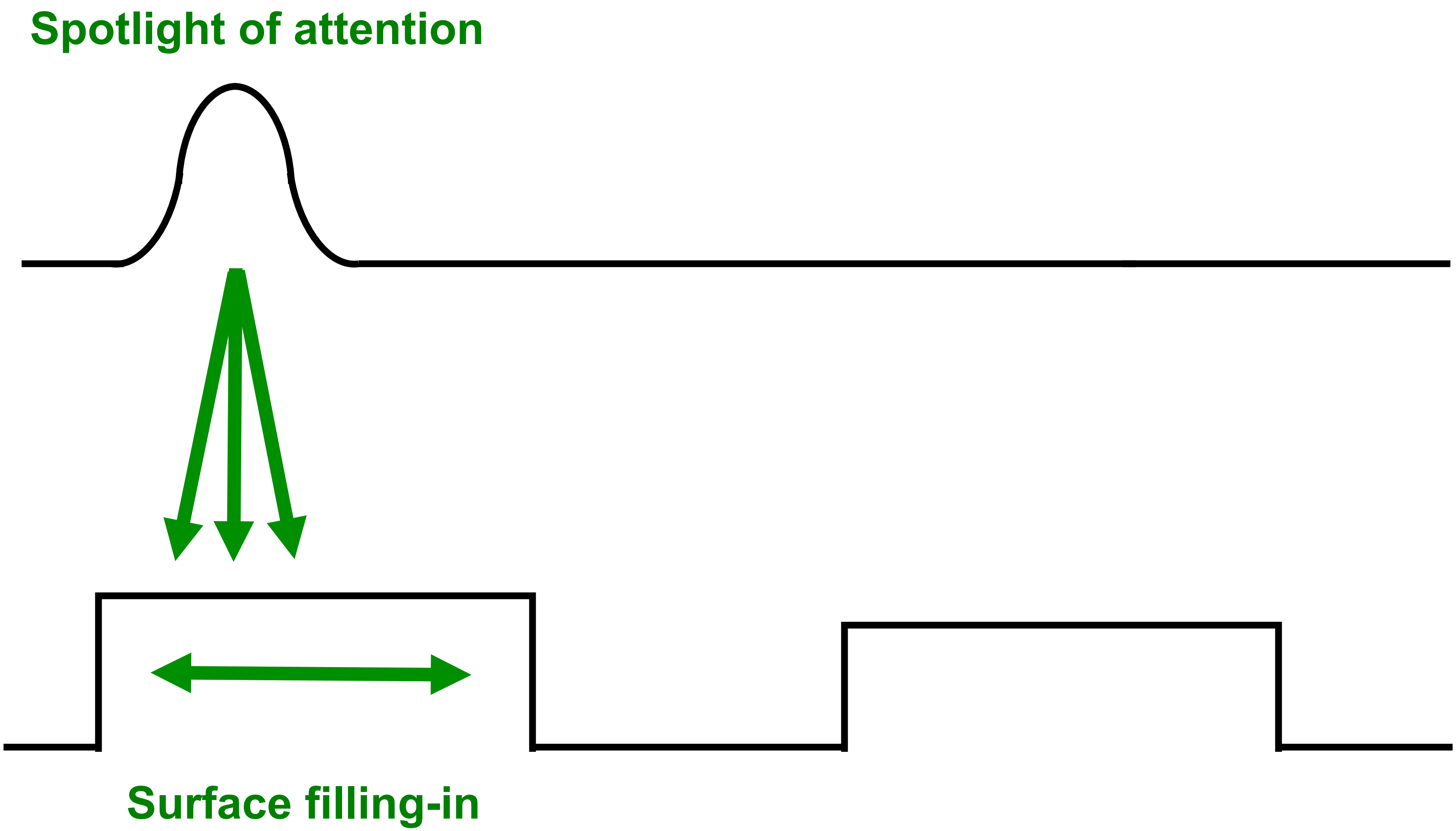
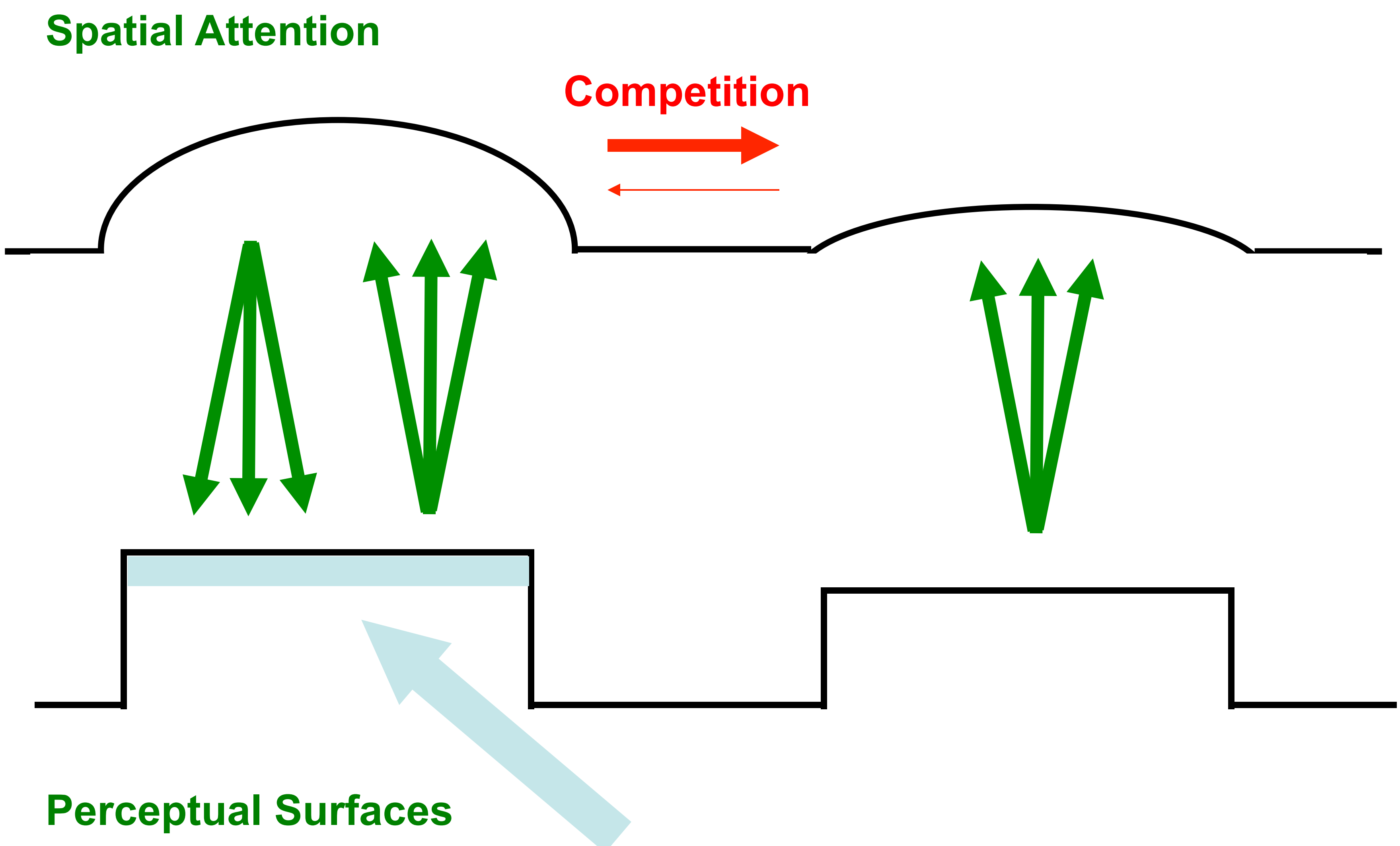
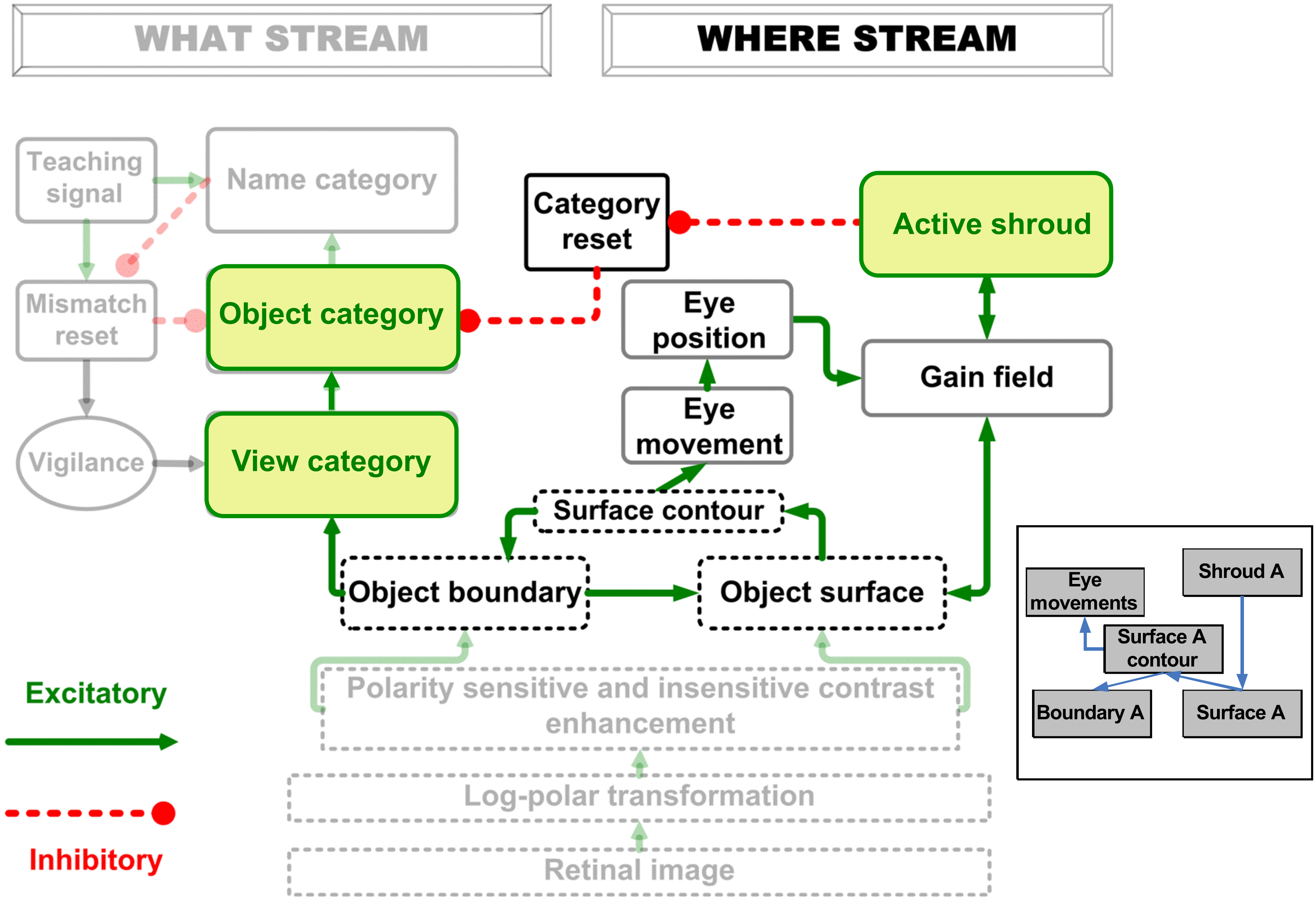


SURFACE-SHROUD RESONANCE AGAIN



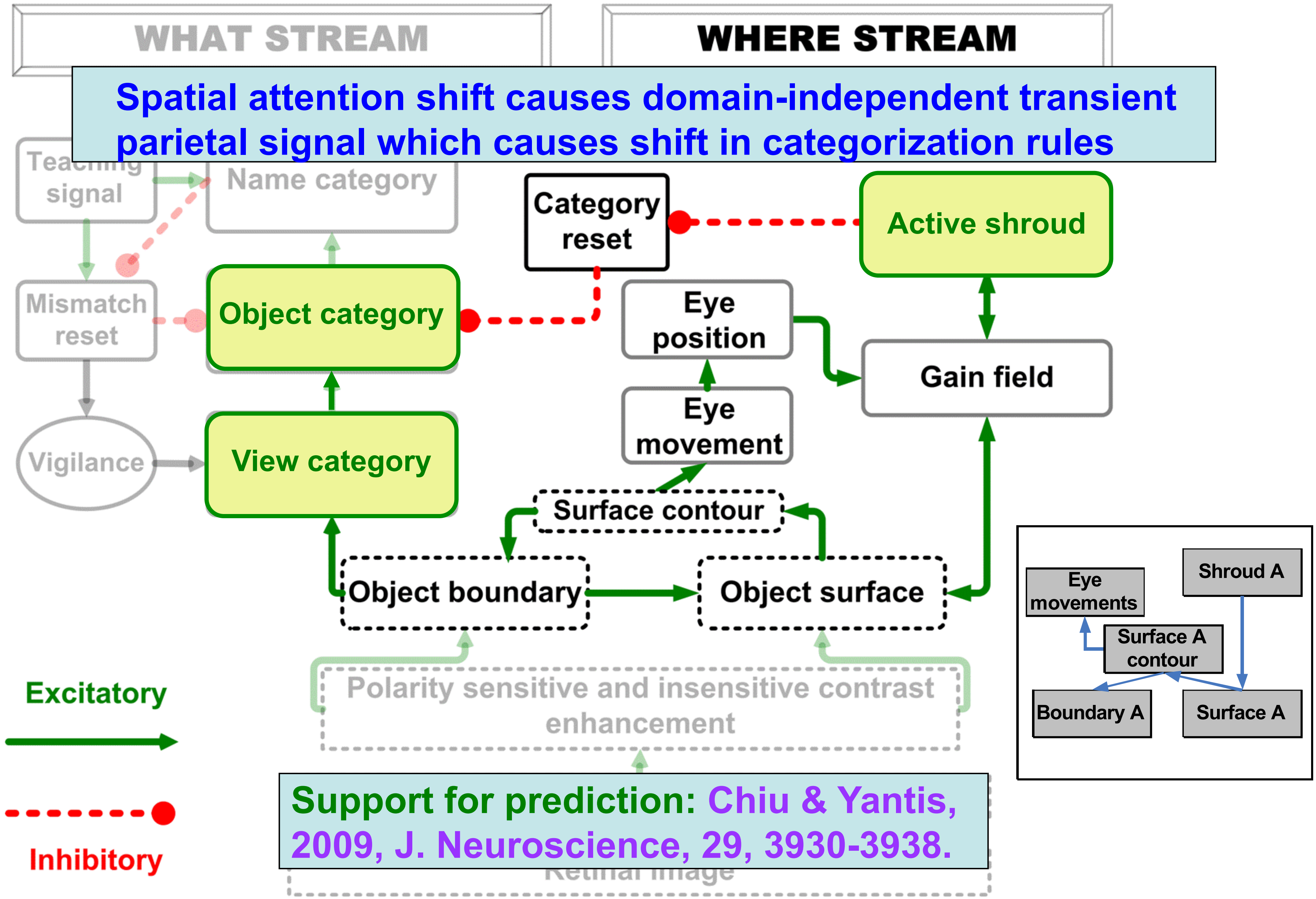
Carrasco, Penpeci-Talgar, & Eckstein (2000)
Reynolds & Desimone (2003)

AN ACTIVE SHROUD MAINTAINS ACTIVITY OF A VIEW-INVARIANT OBJECT CATEGORY AS EYES MOVE



AN ACTIVE SHROUD MAINTAINS ACTIVITY OF A VIEW-INVARIANT OBJECT CATEGORY AS EYES MOVE

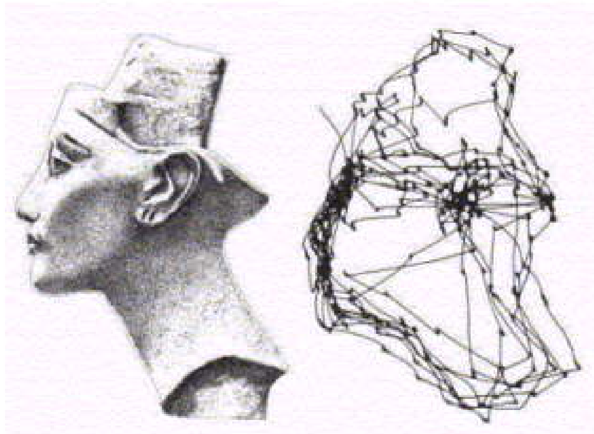
Spatial attention shift causes domain-independent transient parietal signal which causes shift in categorization rules



Support for prediction: Chiu & Yantis, 2009, J. Neuroscience, 29, 3930-3938.

HOW DO WE KNOW WHERE TO LOOK NEXT?

Why don't our eyes jump around randomly?



Yarbus (1961)

How does the brain know how to scan salient features of objects?

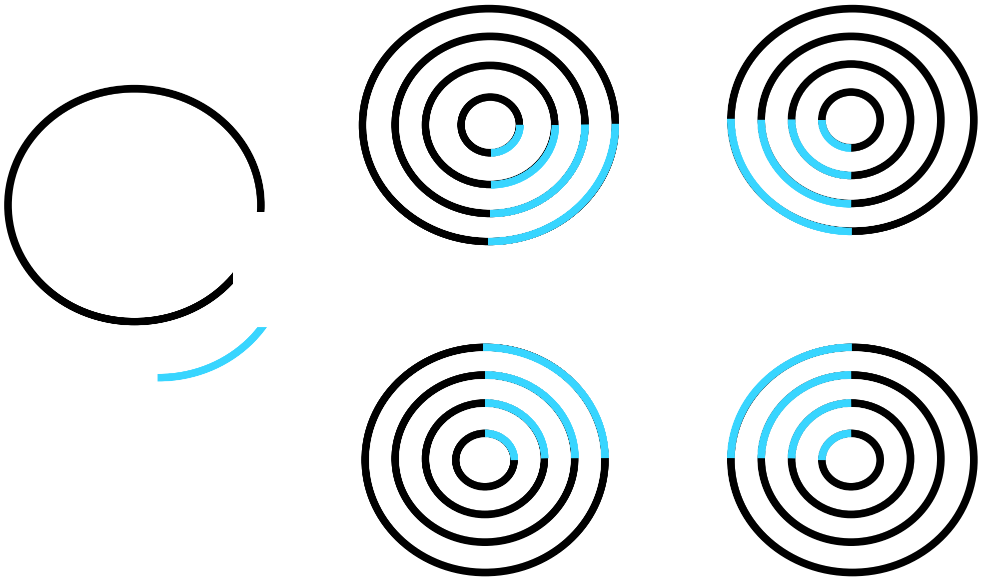
How do scanning movements occur within an object even before an object category is defined?

Object, not pixel, based movement!

Movement targets must be selected after surfaces get separated from each other via figure-ground separation

VISUAL BOUNDARY AND SURFACE COMPUTATIONS ARE COMPLEMENTARY

Grossberg (1987, 1994)

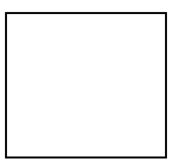


Neon color spreading

How do complementary boundaries and surfaces give rise to a consistent percept?

This process clarifies how figure-ground separation and eye movement search occur!

BOUNDARY COMPLETION

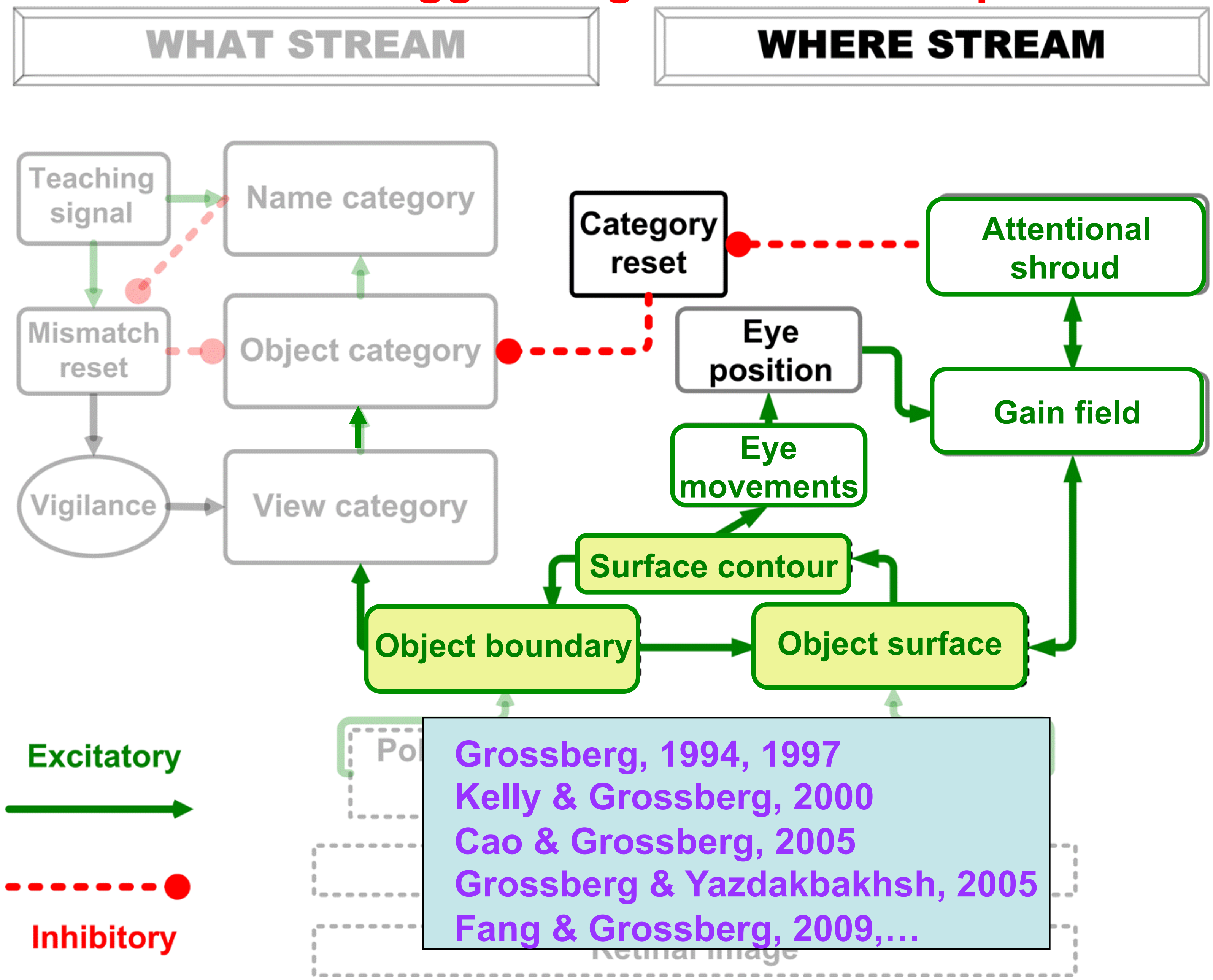


oriented
inward
insensitive to direction-of-contrast

SURFACE FILLING-IN

unoriented
outward
sensitive to direction-of-contrast

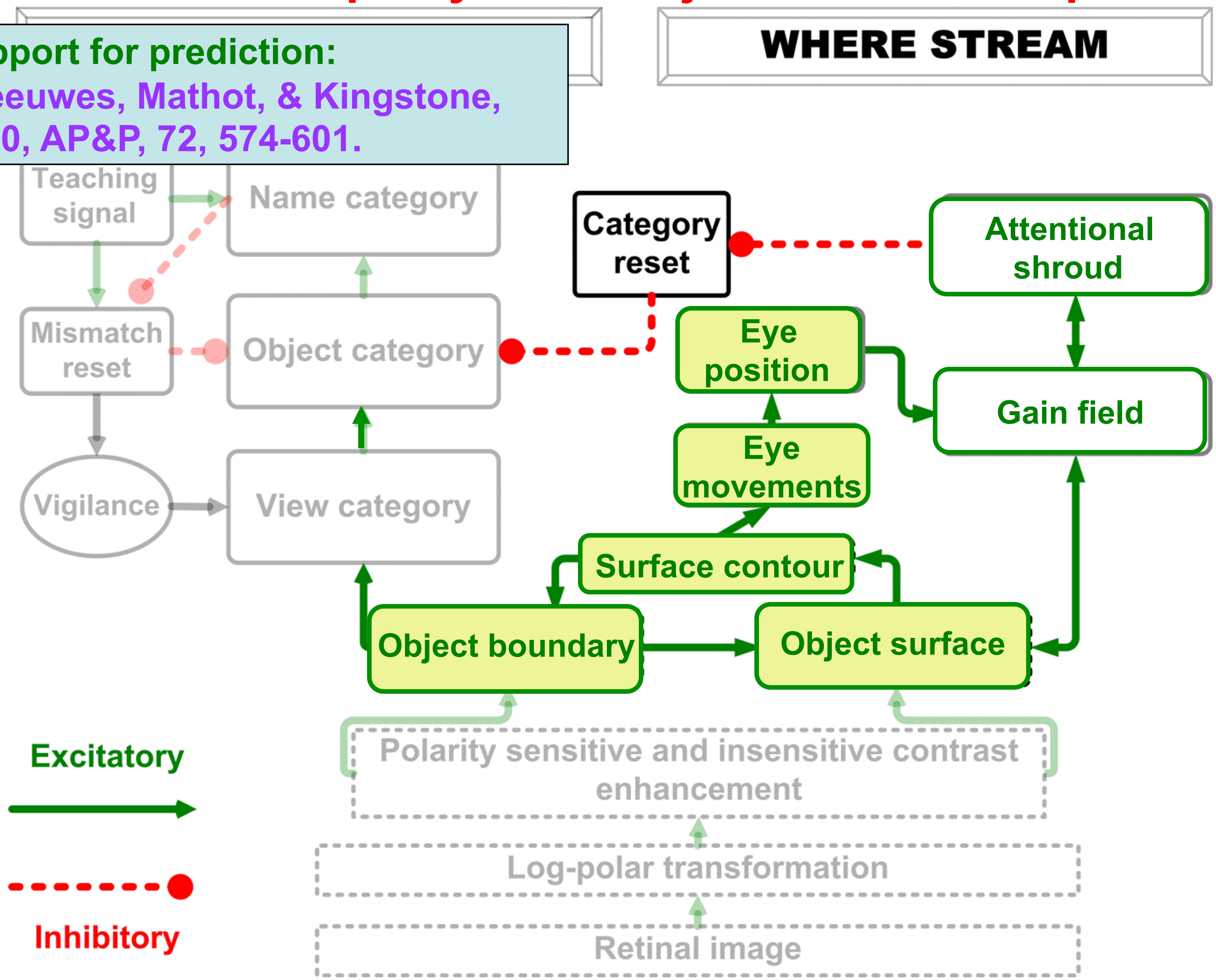
Consistent Percept due to Feedback Between Boundaries and Surfaces: Triggers Figure-Ground Separation



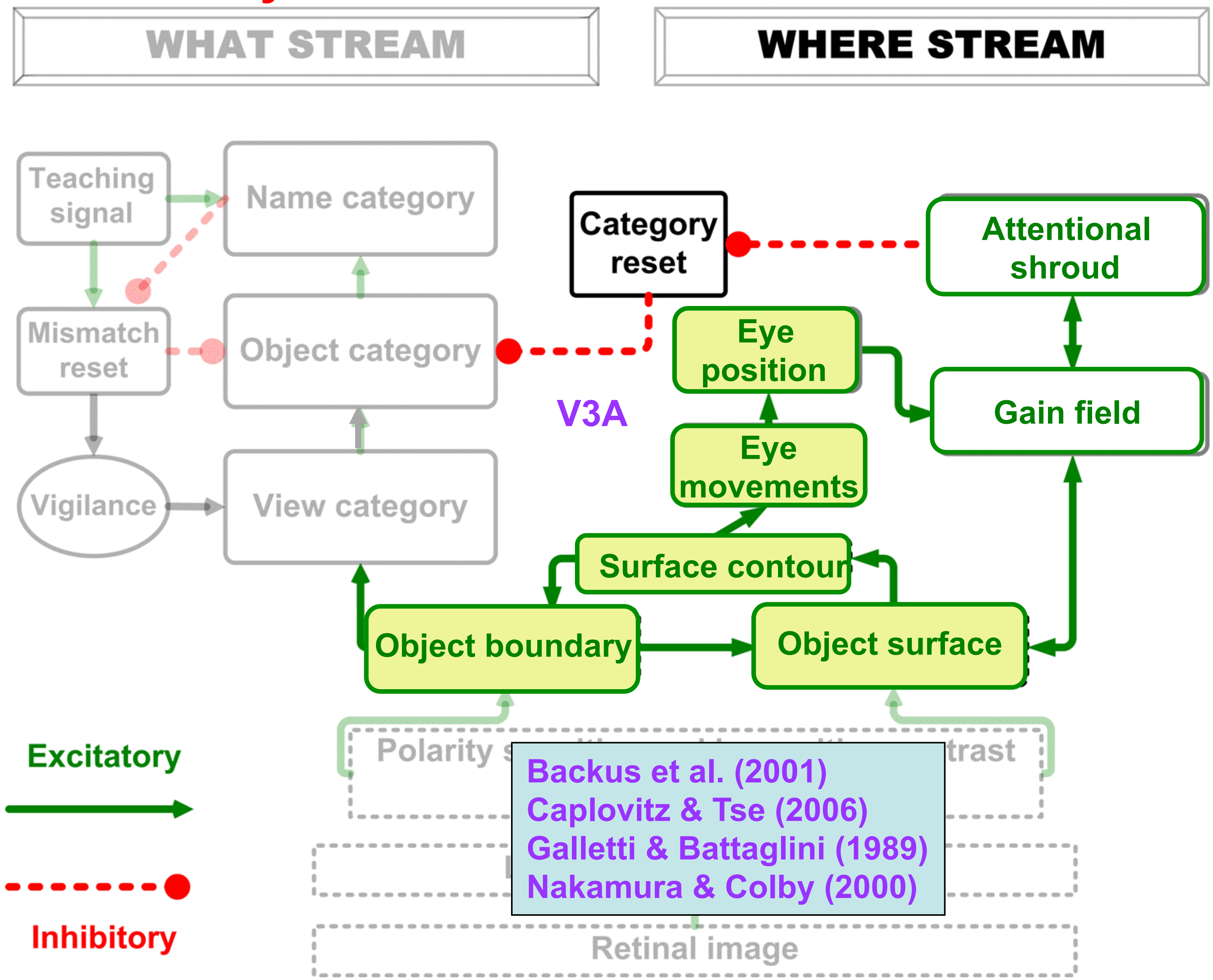
Grossberg, 1994, 1997
Kelly & Grossberg, 2000
Cao & Grossberg, 2005
Grossberg & Yazdakbakhsh, 2005
Fang & Grossberg, 2009,…

Figure-Ground Circuit Outputs Control Eye Movements! Shroud Keeps Eyes on Object Until It Collapses

Support for prediction:
Theeuwes, Mathot, & Kingstone, 2010, AP&P, 72, 574-601.

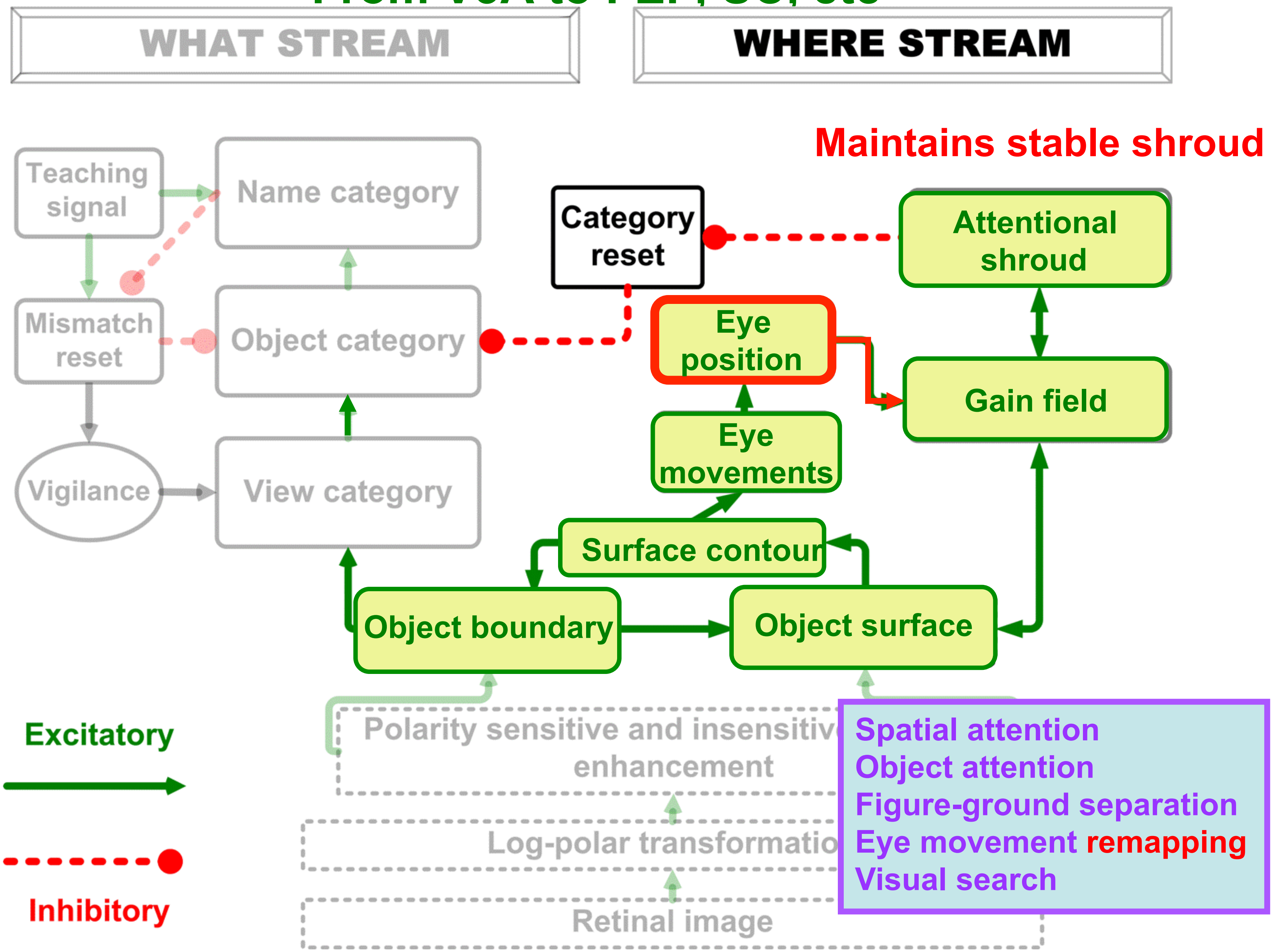


Where in the Brain Are Surface Contours Converted into Eye Movement Commands? V3A?

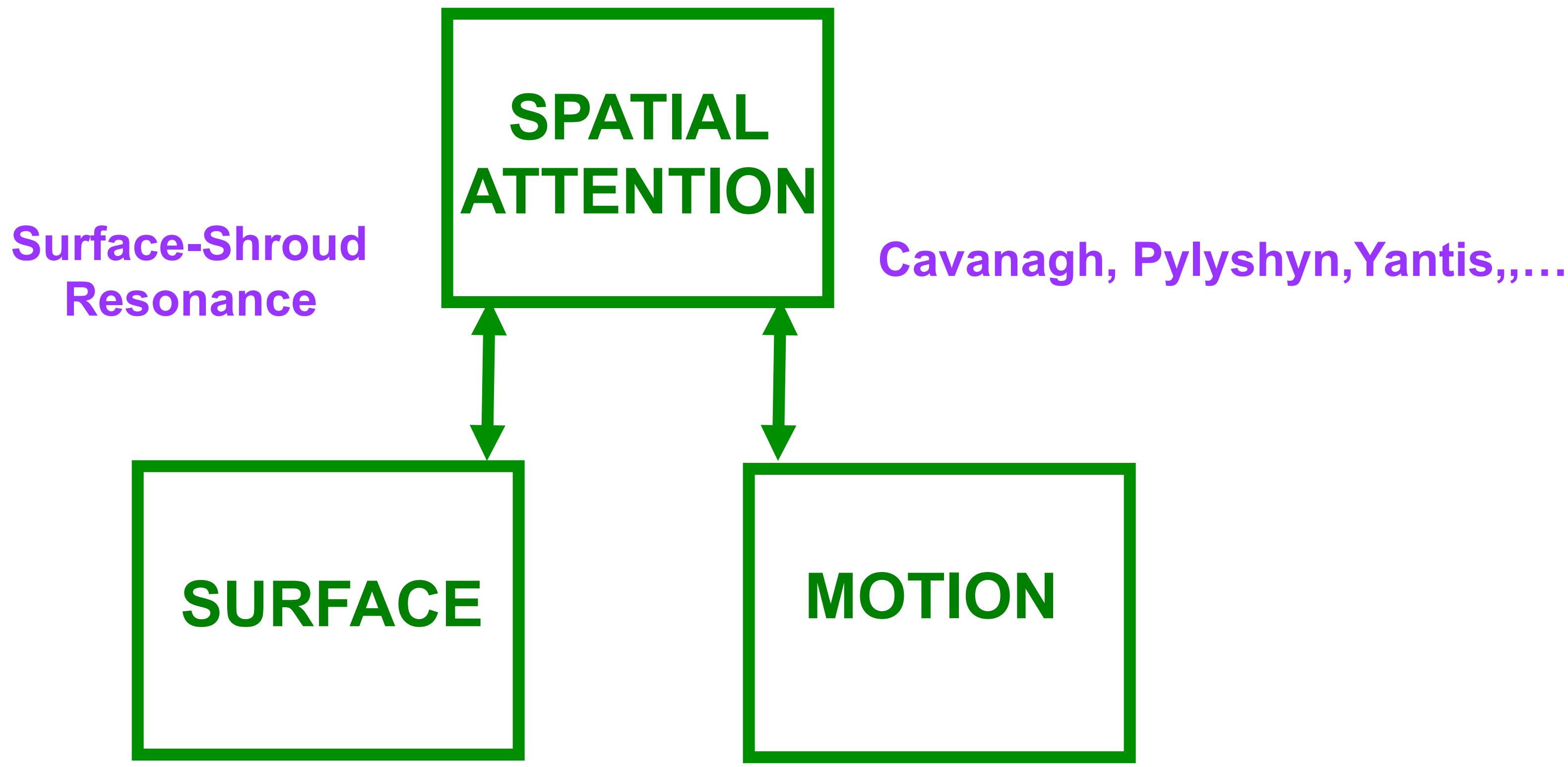


PREDICTIVE REMAPPING BY EYE MOVEMENT COMMANDS!

From V3A to FEF, SC, etc



SURFACES in the WHAT cortical stream and MOTION TRANSIENTS in the WHERE stream can both attract SPATIAL ATTENTION

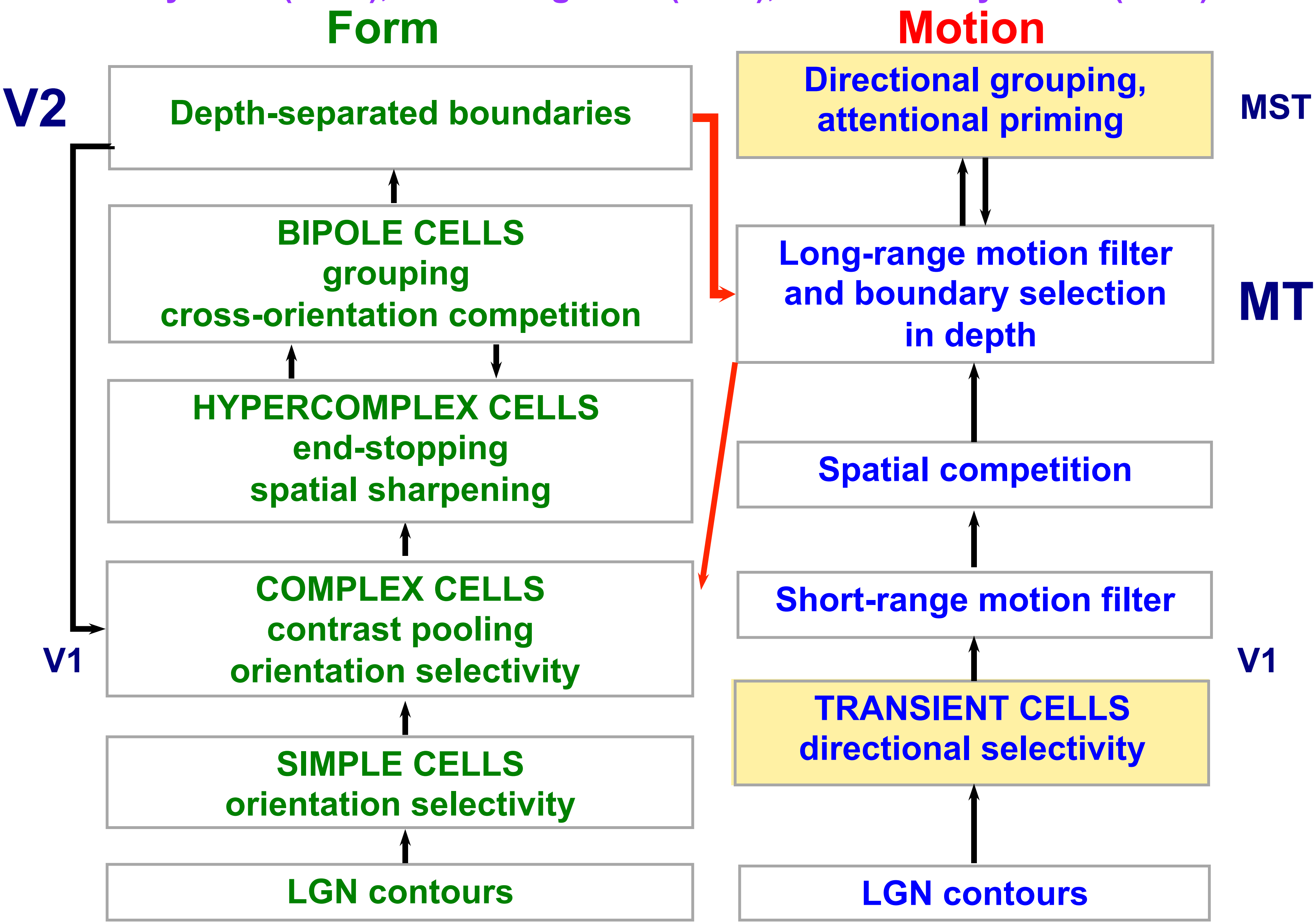


Clarifies how a SURFACE-SHROUD RESONANCE can be attracted to and track a moving object; e.g., teacher's moving face or hand …also learn "action understanding" categories of, say, throwing a ball

To do this, need to integrate yet other models into the CRIB:

3D FORMOTION MODEL

Chey et al. (1997), Grossberg et al. (2001), Berzhanskaya et al. (2007)

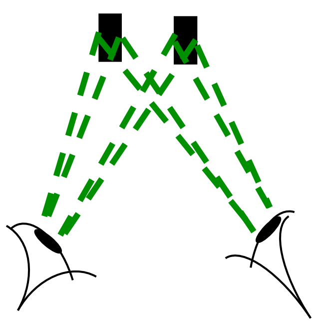


A RECENTLY CONFIRMED PREDICTION

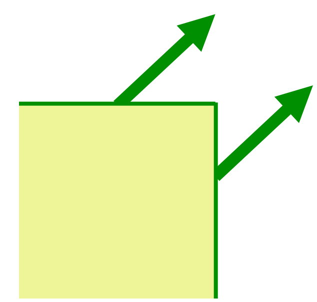
FORM and MOTION are COMPLEMENTARY

Prediction: Grossberg (1991, Perception & Psychophysics)
Data: Ponce, Lomber, & Born (2008, Nature Neuroscience)

Why separate cortical FORM and MOTION streams?



V1-V2-V4	V1-MT-MST
orientational	directional
fine depth	fine direction
coarse direction	coarse depth



Prediction:

V2- MT interaction achieves fine moving-form-in-depth which facilitates object tracking, etc.

Ponce et al cooled V2 and studied the effect on MT of depth and direction processing

HOW IS ATTENTION ATTRACTED TO A VALUED OBJECT LIKE A MOTHER'S FACE?

Show how *motivated* attention can amplify invariant categories
The Cognitive-Emotional Motor (CogEM) model can do this

Show how to use a motivationally-enhanced positionally-invariant face category to look at a face at a particular position in space?
How to link a *positionally-invariant* category to its *position*?
COMPLEMENTARITY!

To do this: Solve the WHERE'S WALDO PROBLEM:
Find a desired object at a particular position in a cluttered scene

Why do I mention WHERE'S WALDO now?
CLAIM: This problem can be solved using an extension of ARTSCAN

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Why does this happen to INVARIANT categories?

An invariant category representation can easily resonate with a source of motivated attention signals to amplify its activity

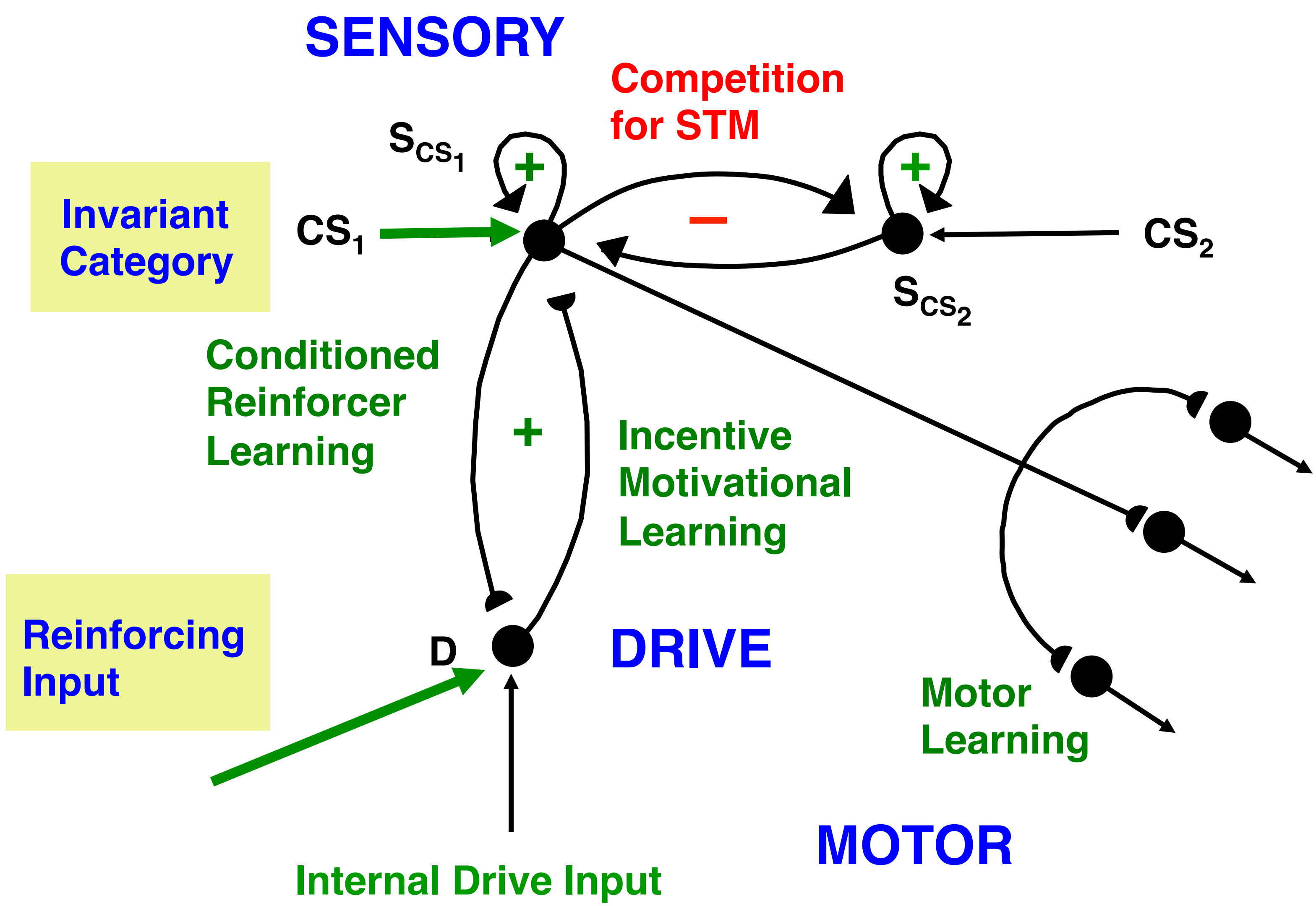
Don't need to amplify lots of position-, size-, and view-dependent categories separately
…avoids a combinatorial explosion

SEVERAL KINDS OF LEARNING AND MEMORY NEEDED FOR THE EMERGENCE OF SELF

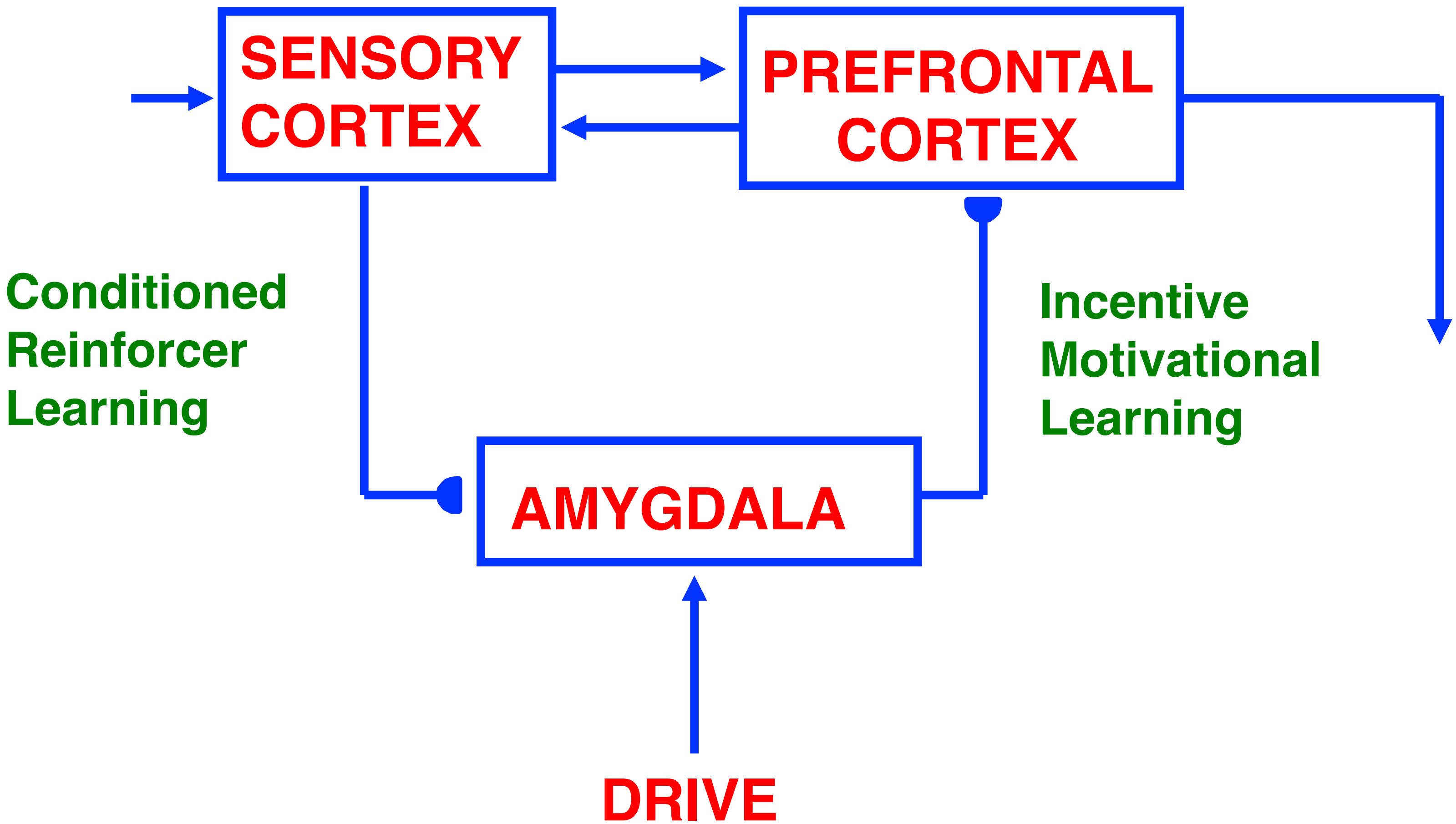
Recognition	Identify	What
Reinforcement	Evaluate	Why
Timing	Synchronize	When
Spatial	Locate	Where
Motor Control	Act	How

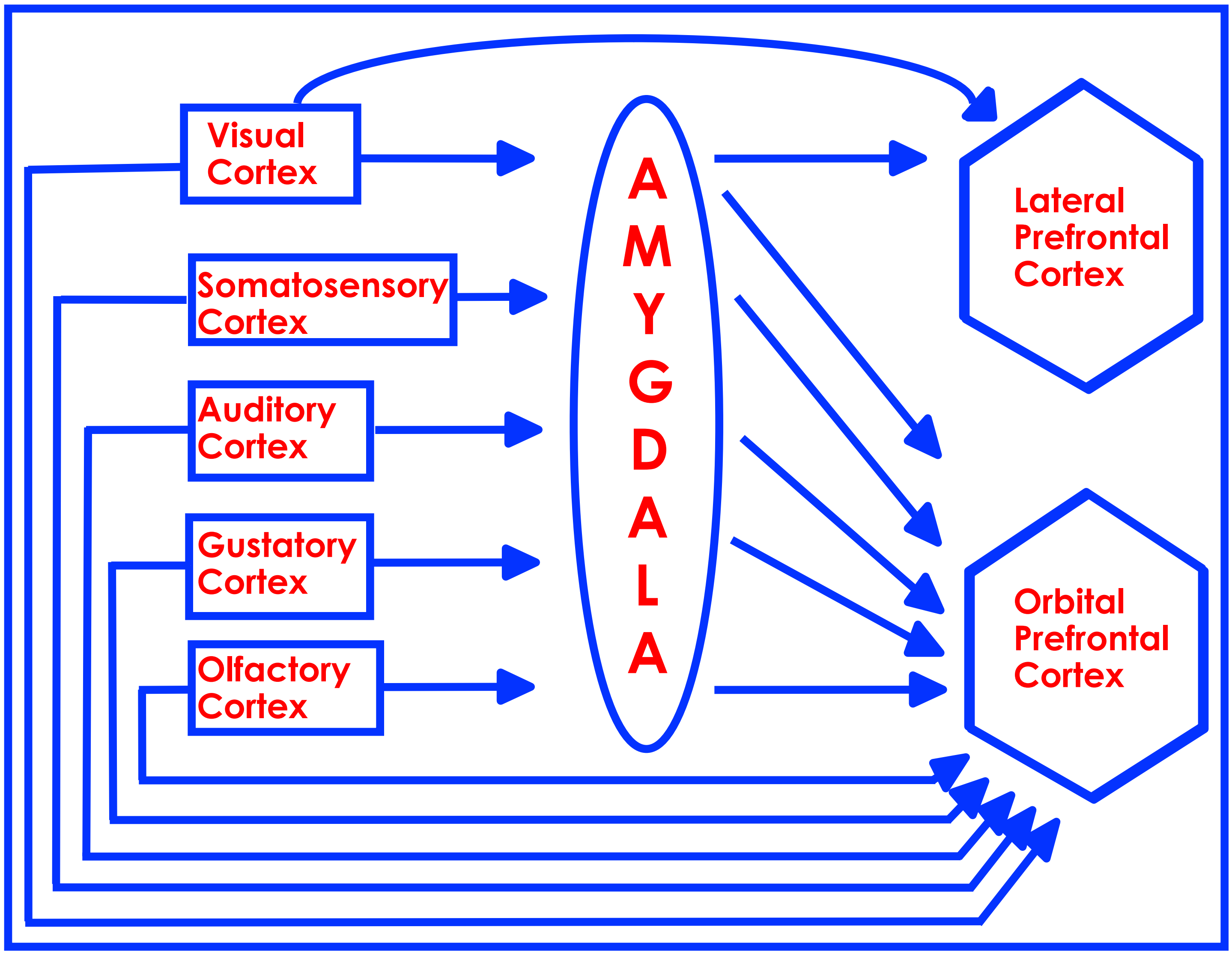
…and they interact!

CogEM MODEL:
3 Types of Representations and Learning
Grossberg, 1971+



INTERPRETATION OF CogEM ANATOMY

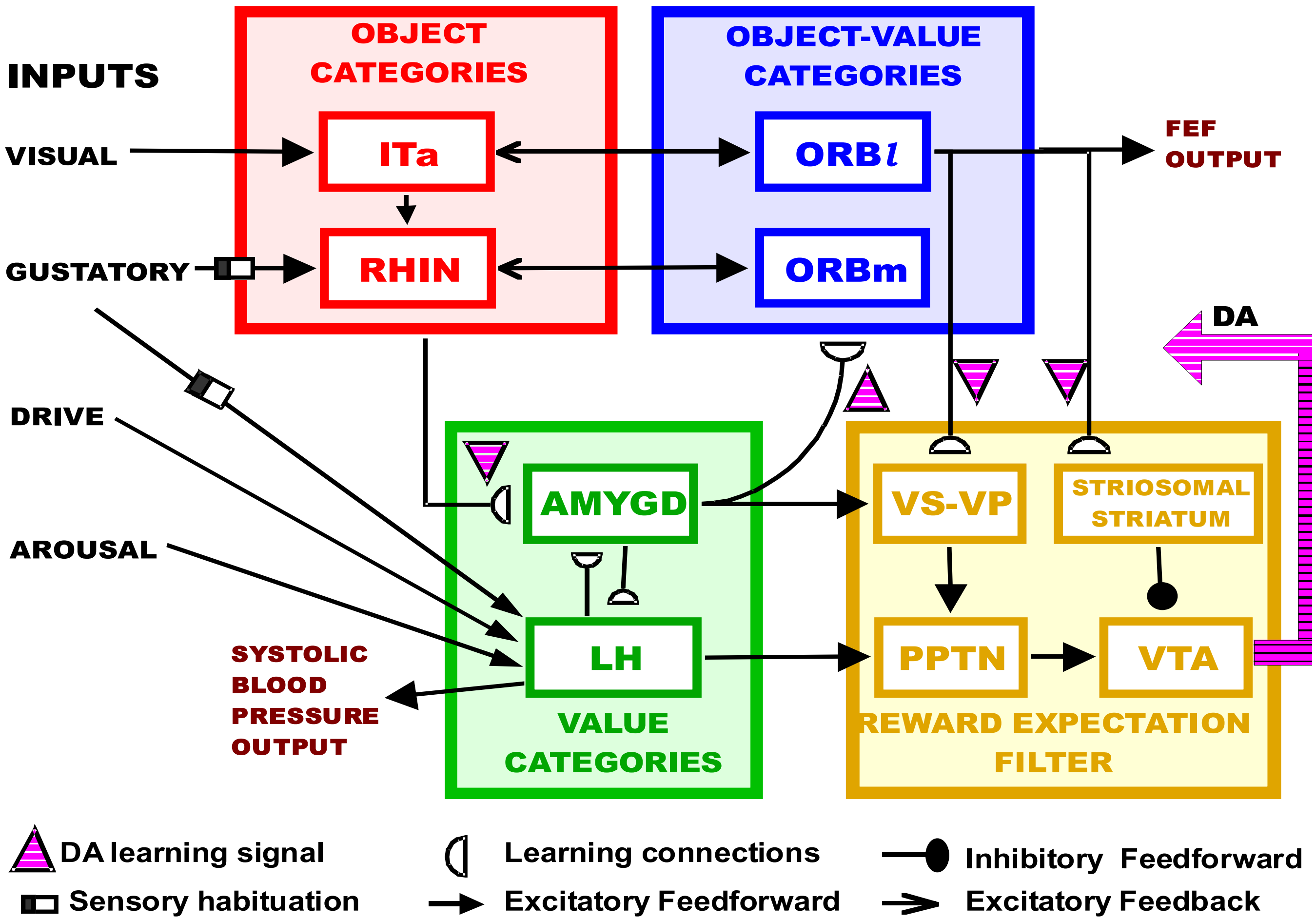




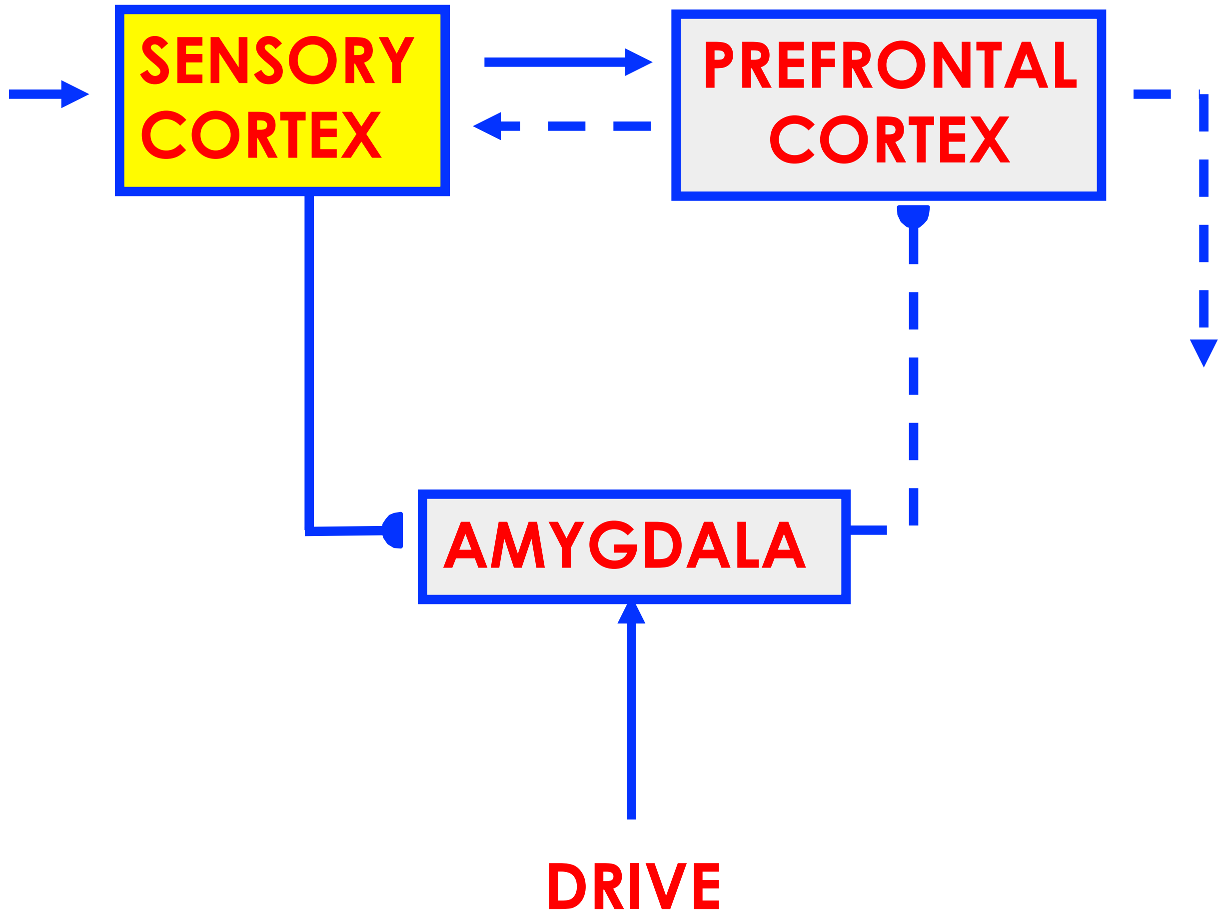
Adapted from Barbas (1995)

MOTIVATOR model

Dranias, Grossberg, & Bullock, 2008; Grossberg, Dranias, & Bullock, 2008

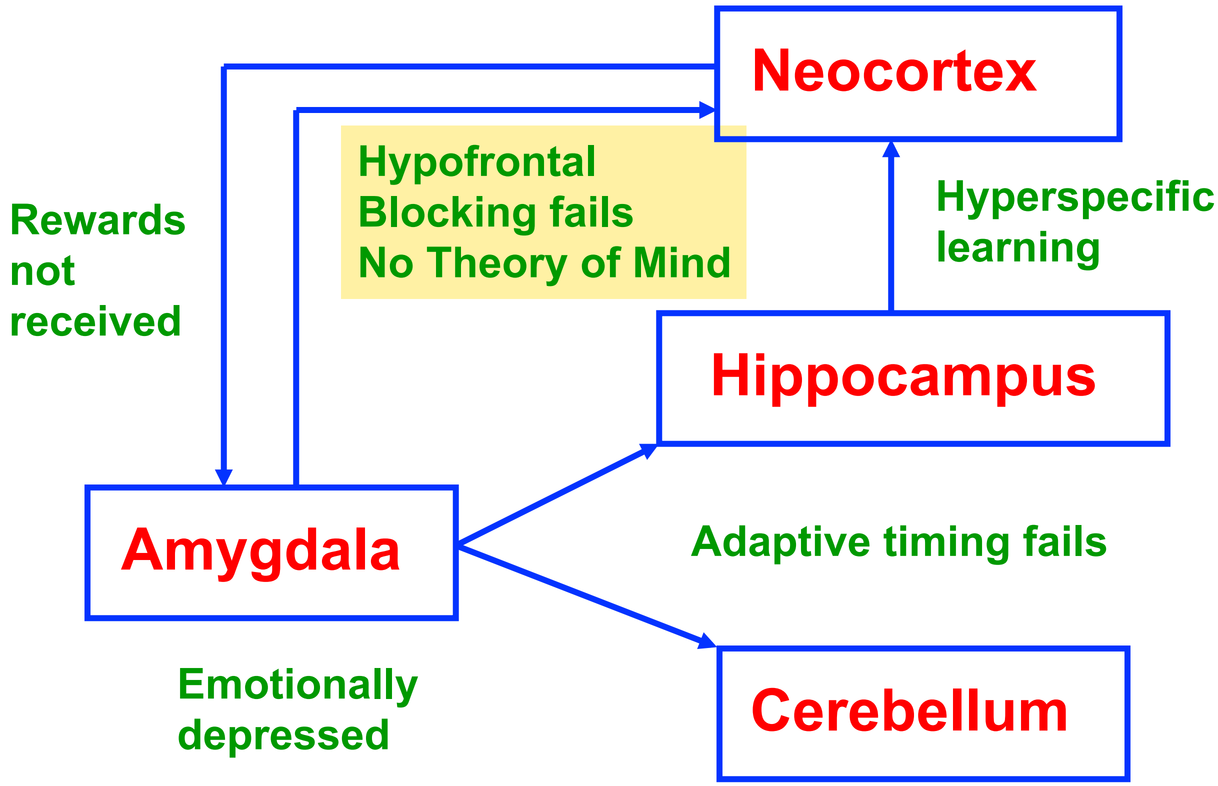


If DRIVE representation (e.g., AMYGDALA) has a DEPRESSED affective response to inputs, lose THEORY OF MIND (AUTISM)



MULTIPLE PROBLEMS DURING AUTISM

Grossberg and Seidmann (2006, Psychological Review)



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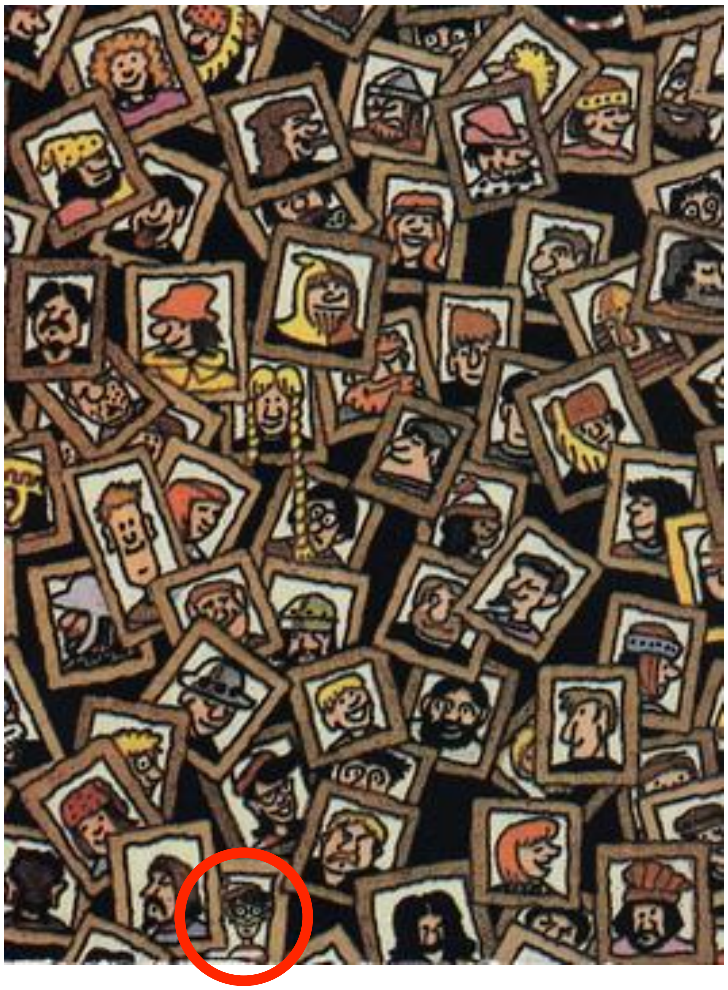
Find a desired object at a particular position in a cluttered scene

Why do I mention WHERE'S WALDO now?
CLAIM: This problem can be solved using an extension of ARTSCAN

WHERE'S WALDO?

To solve this problem, we need to know who is Waldo (WHAT) and where he is (WHERE)

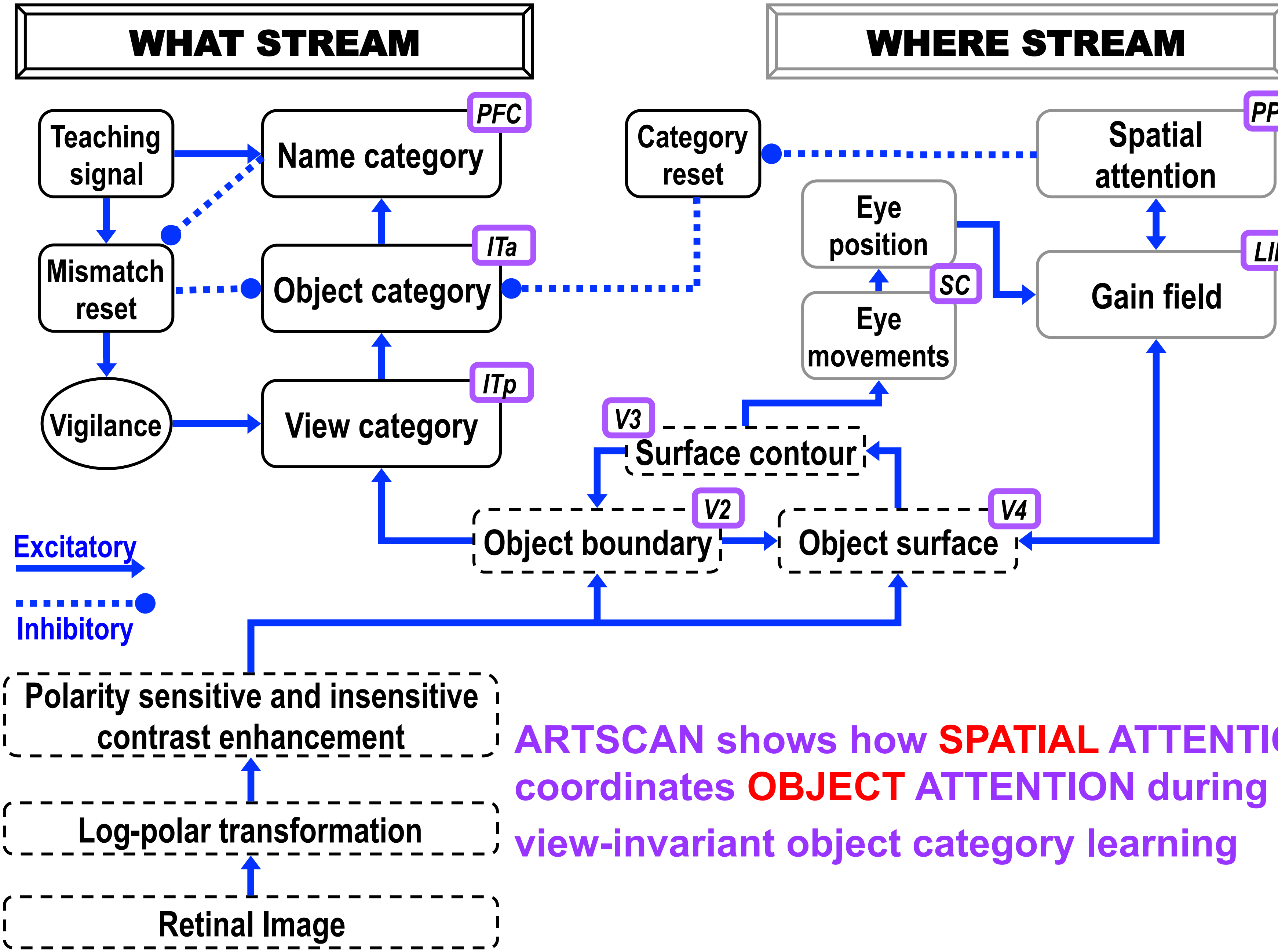


How does the brain locate
a desired object at any location
in a cluttered scene?

How does the brain
learn and recognize
spatially-invariant
object representations?

How does the brain direct
spatial and object attention
and eye movements
to a desired object?

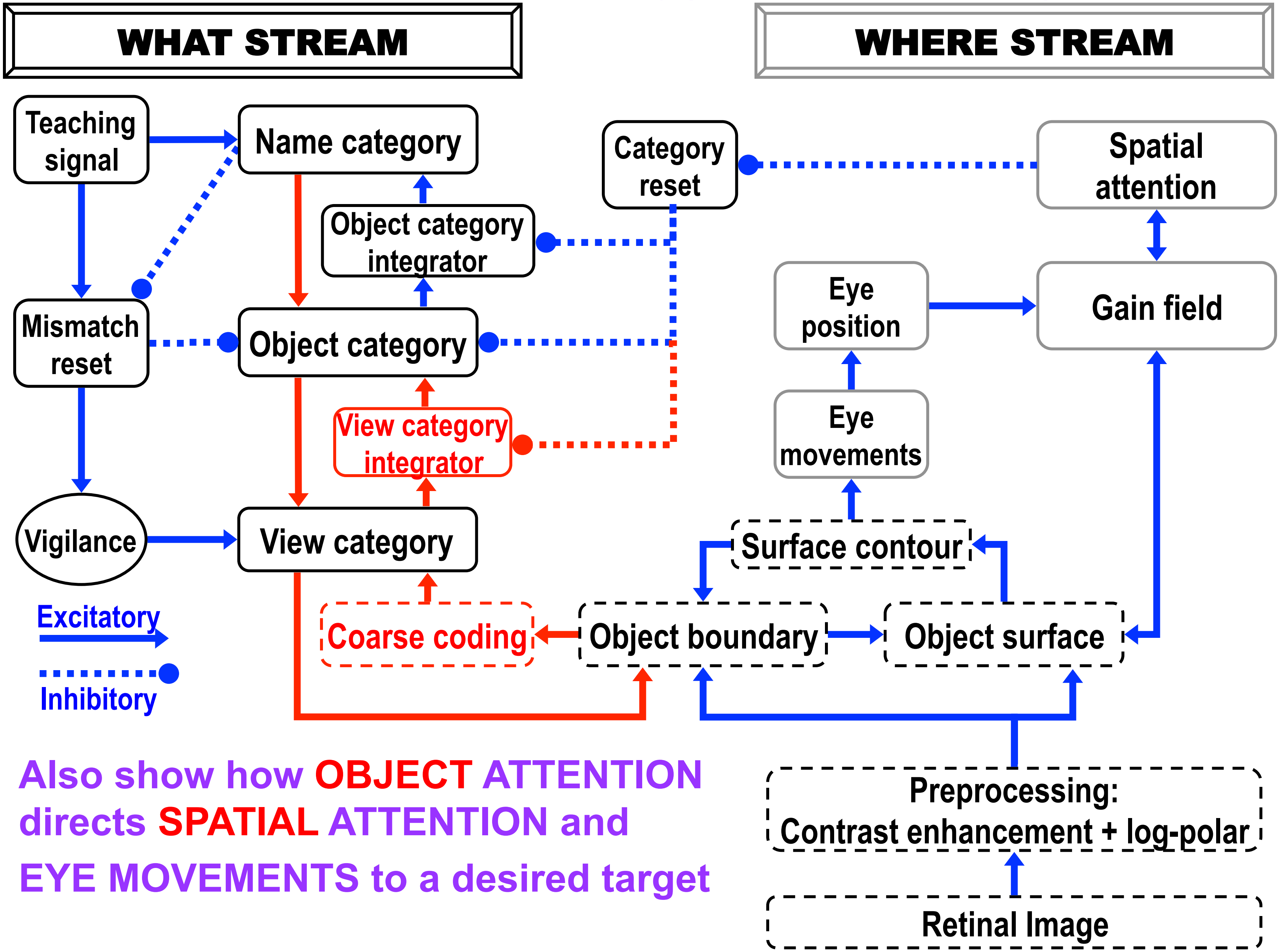
BUILD ON ARTSCAN MODEL: From WHERE to WHAT



ARTSCAN shows how SPATIAL ATTENTION coordinates OBJECT ATTENTION during view-invariant object category learning

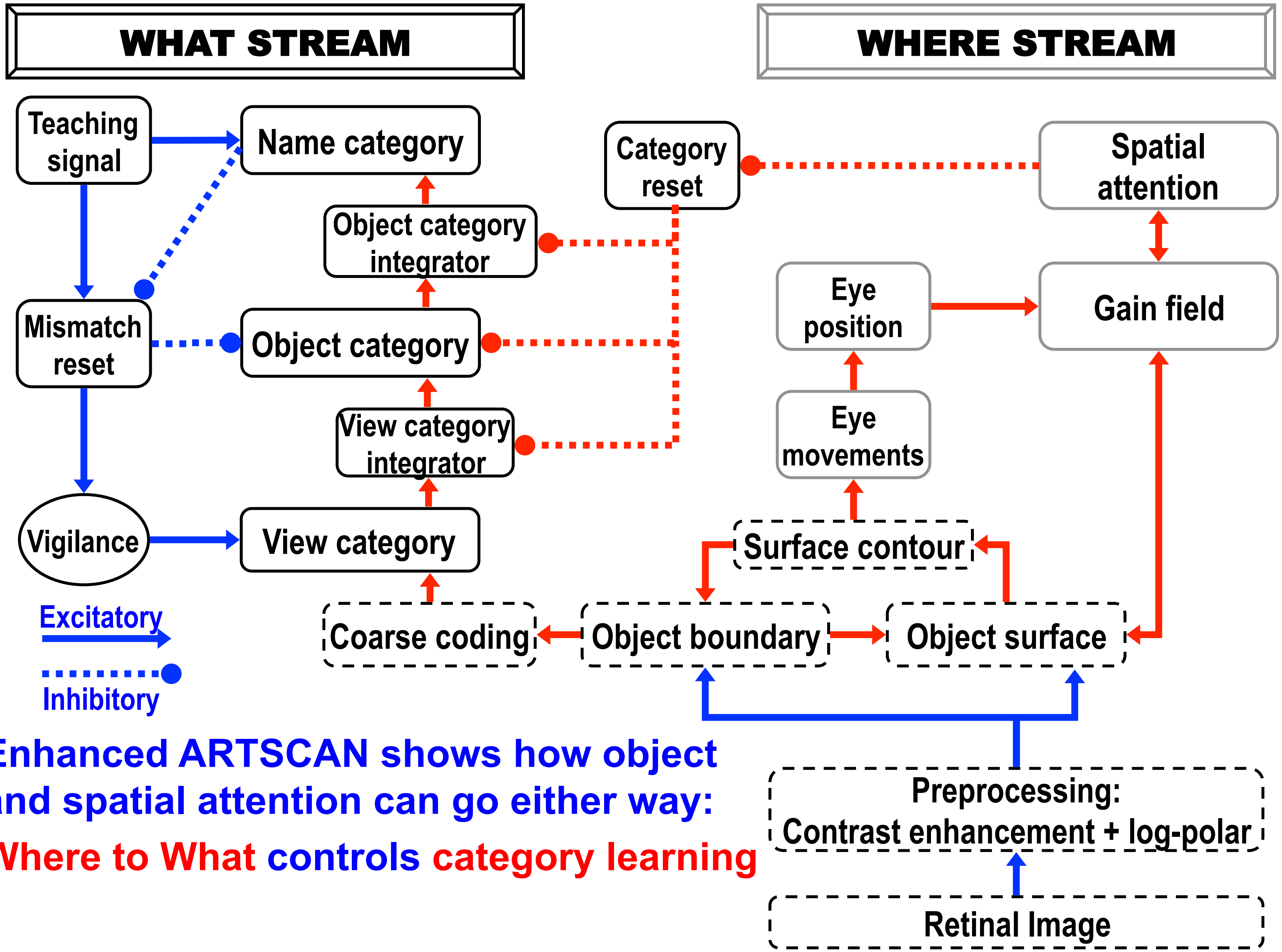
ENHANCED ARTSCAN MODEL: From WHAT to WHERE

Chang, Cao, and Grossberg (2009, SfN; 2010, VSS)



Also show how **OBJECT ATTENTION** directs **SPATIAL ATTENTION** and **EYE MOVEMENTS** to a desired target

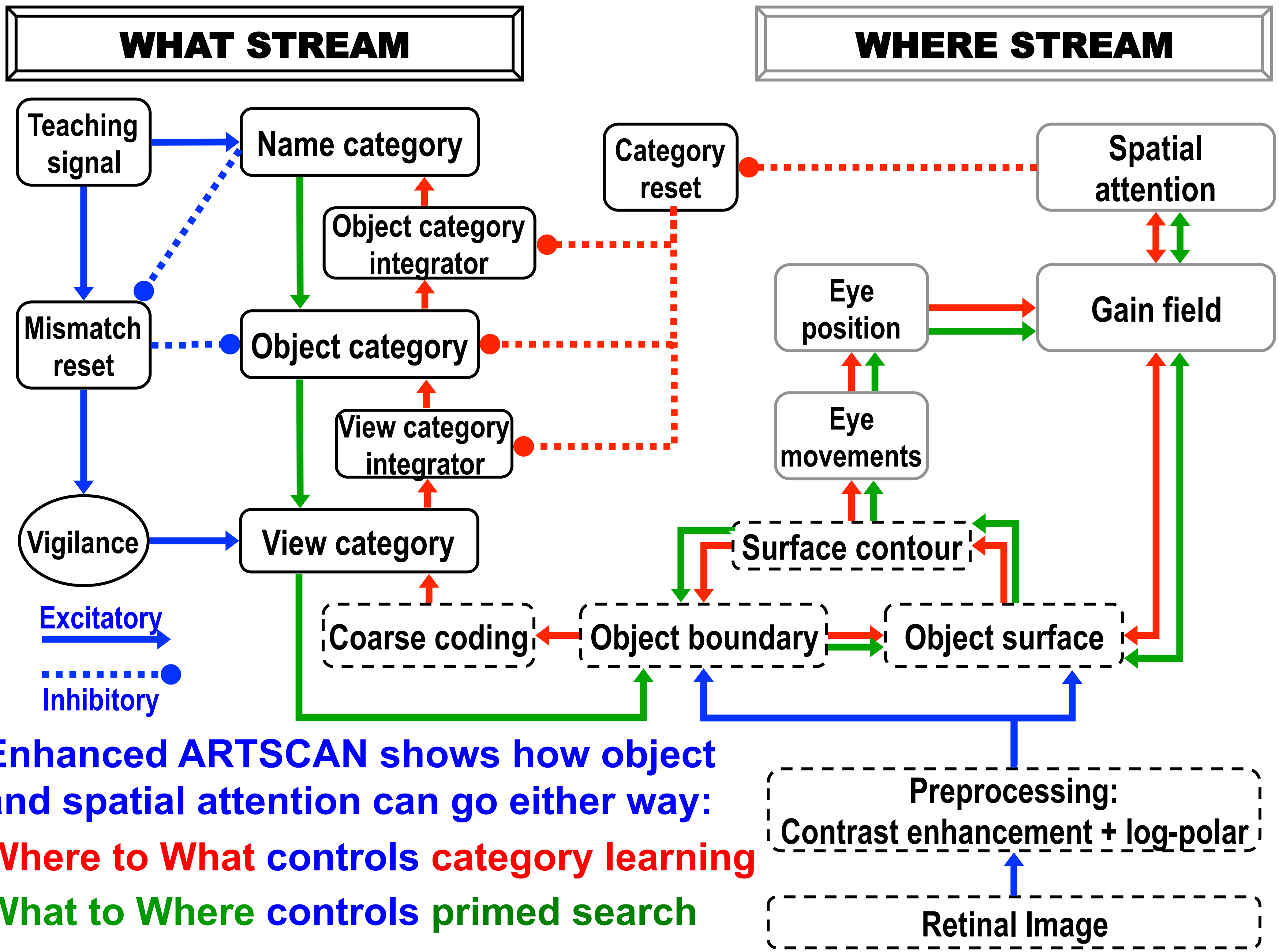
wwARTSCAN: From WHAT to WHERE and BACK



Enhanced ARTSCAN shows how object and spatial attention can go either way:

Where to What controls category learning

wwARTSCAN: From WHAT to WHERE and BACK



Enhanced ARTSCAN shows how object and spatial attention can go either way:

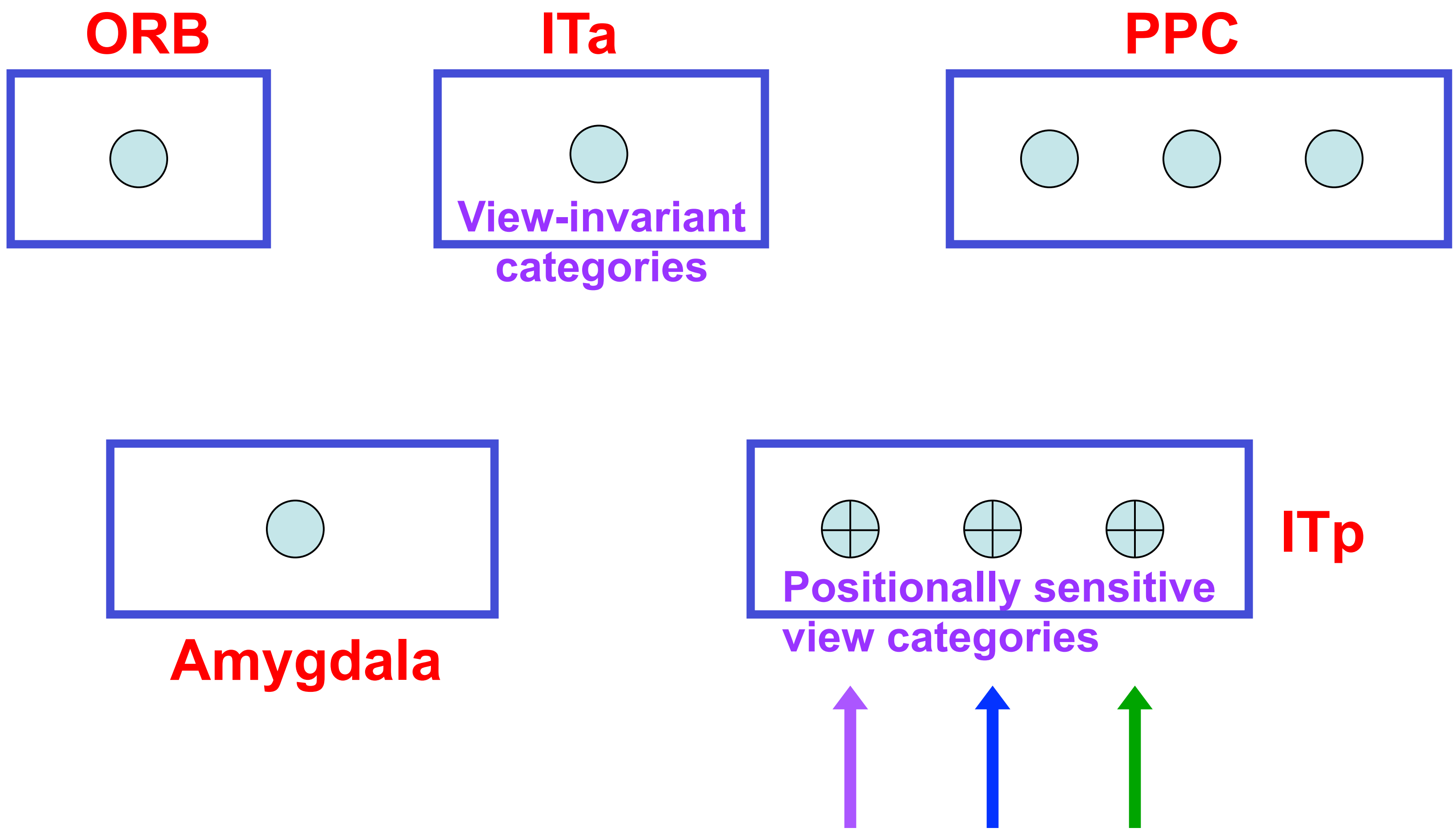
Where to What controls category learning

What to Where controls primed search

Combine CogEM and wwARTSCAN:

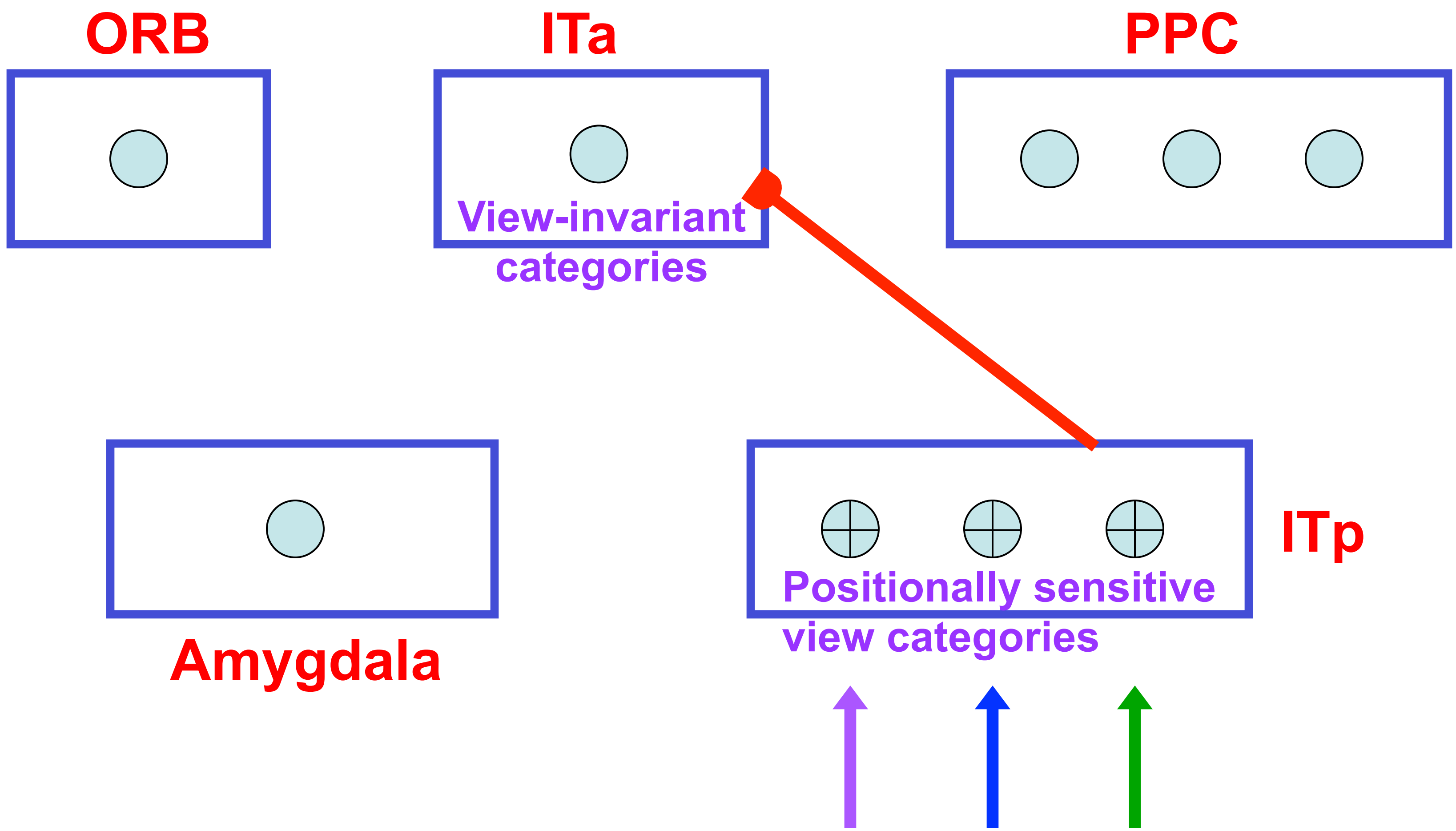
MULTIPLE BRAIN REGIONS GUIDE WALDO SEARCH FROM SCENIC INPUT TO WALDO DISCOVERY

Bottom-up scenic inputs activate ITp cells that combine feature and position information



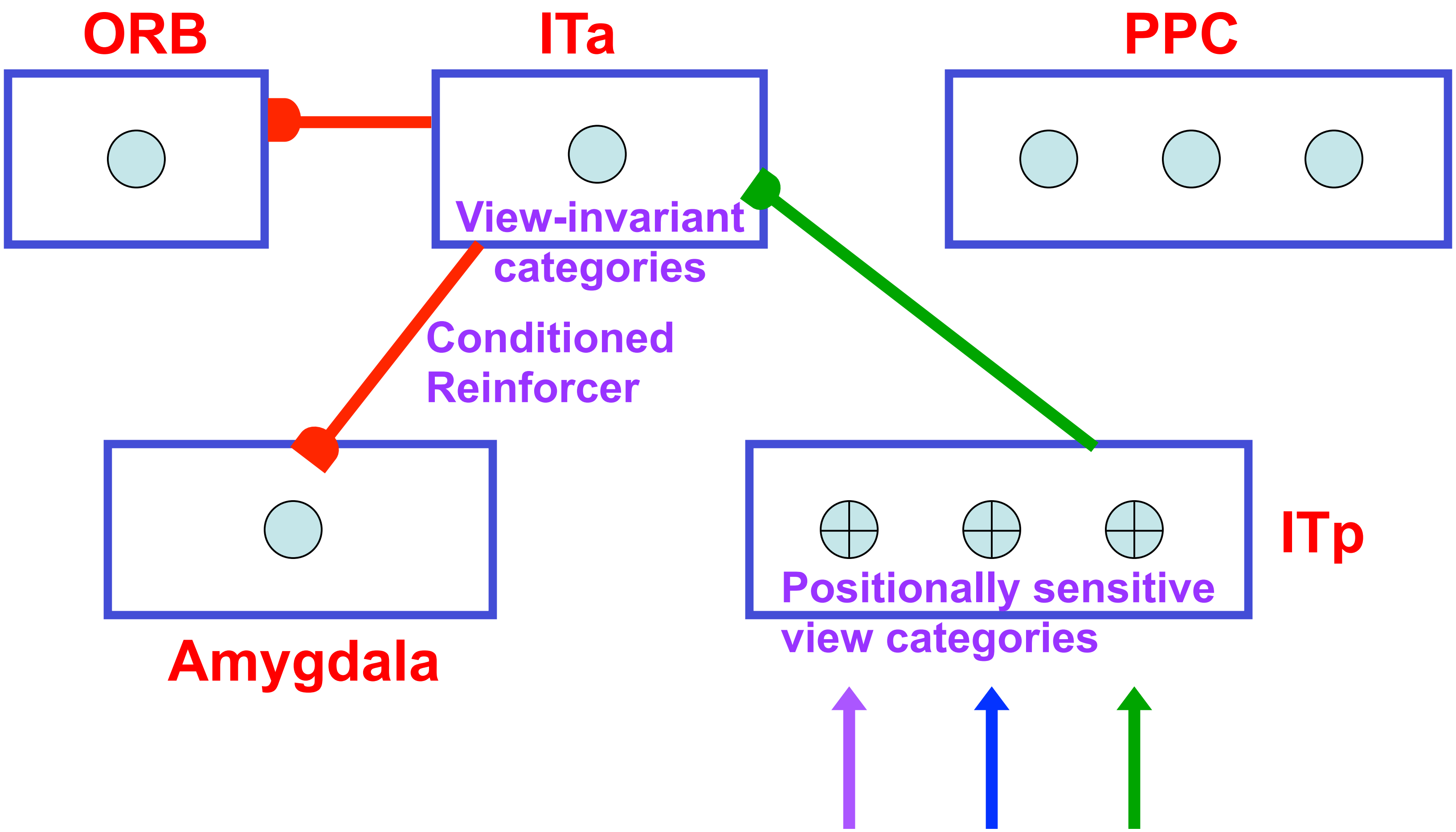
MULTIPLE BRAIN REGIONS GUIDE WALDO SEARCH FROM SCENIC INPUT TO WALDO DISCOVERY

ITp cells activate view-invariant
object categories in ITa



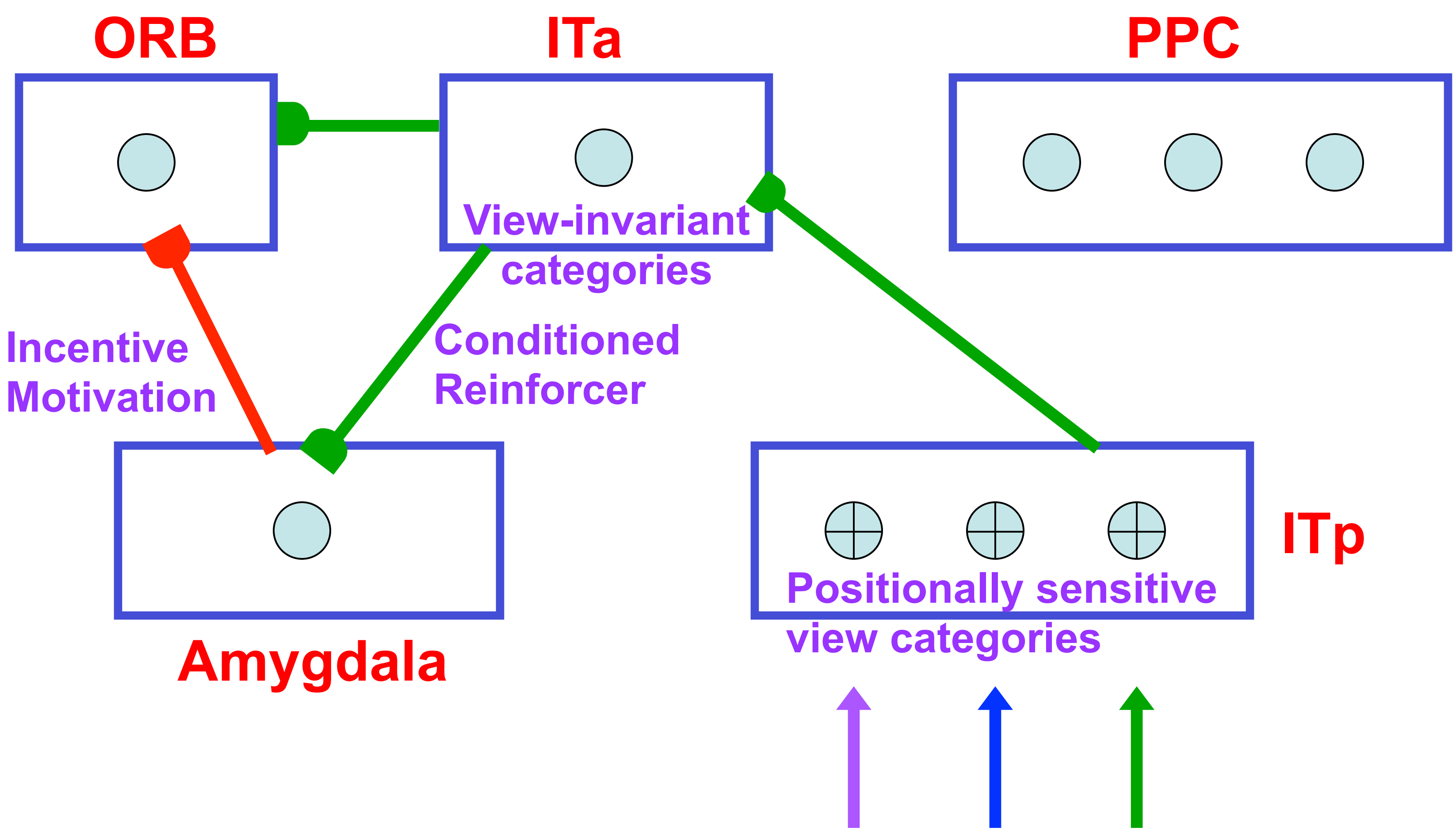
MULTIPLE BRAIN REGIONS GUIDE WALDO SEARCH FROM SCENIC INPUT TO WALDO DISCOVERY

ITa category activates amygdala
and orbitofrontal cortex



MULTIPLE BRAIN REGIONS GUIDE WALDO SEARCH FROM SCENIC INPUT TO WALDO DISCOVERY

Convergent ITa and amygdala input activates object-value ORB cells



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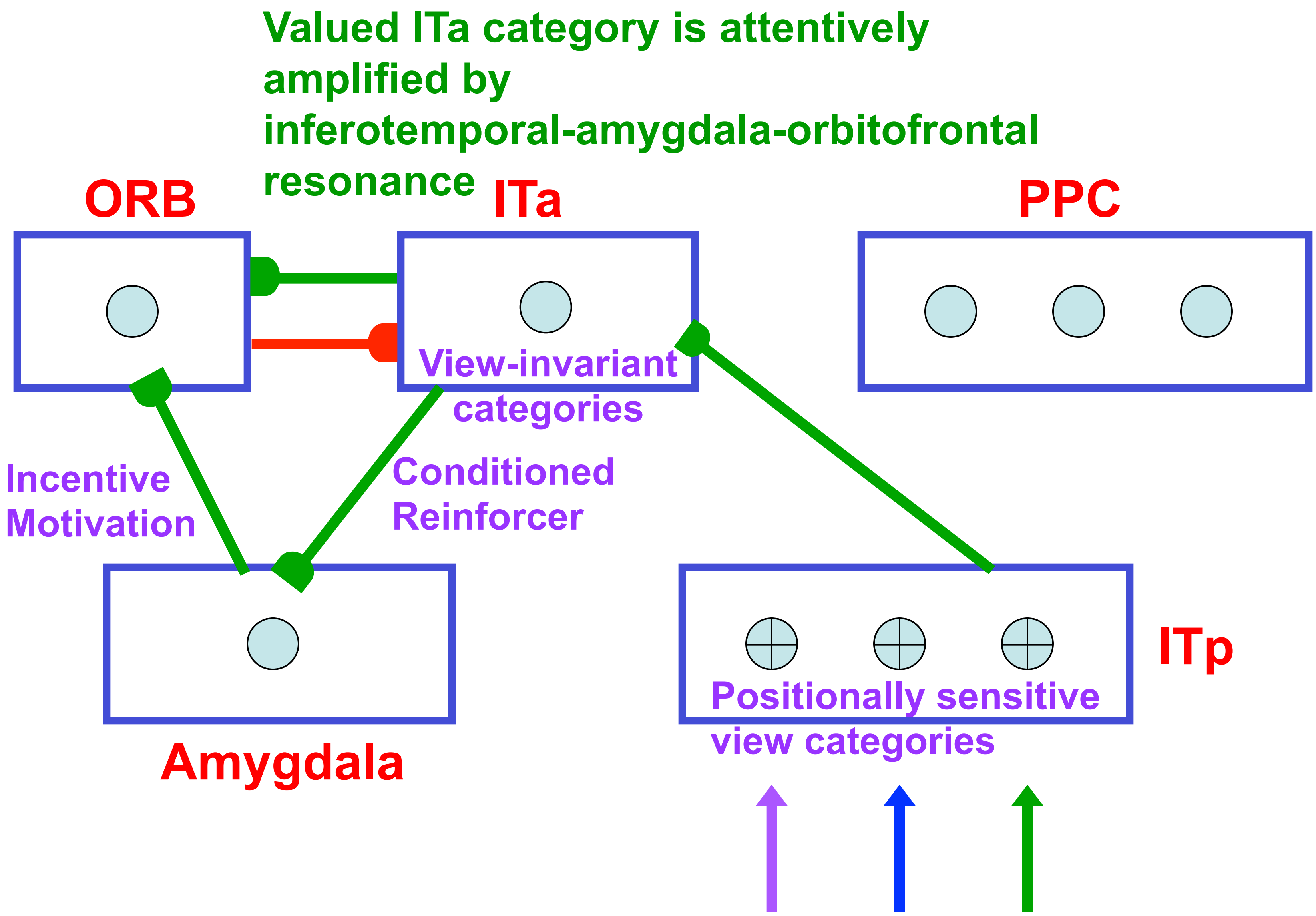
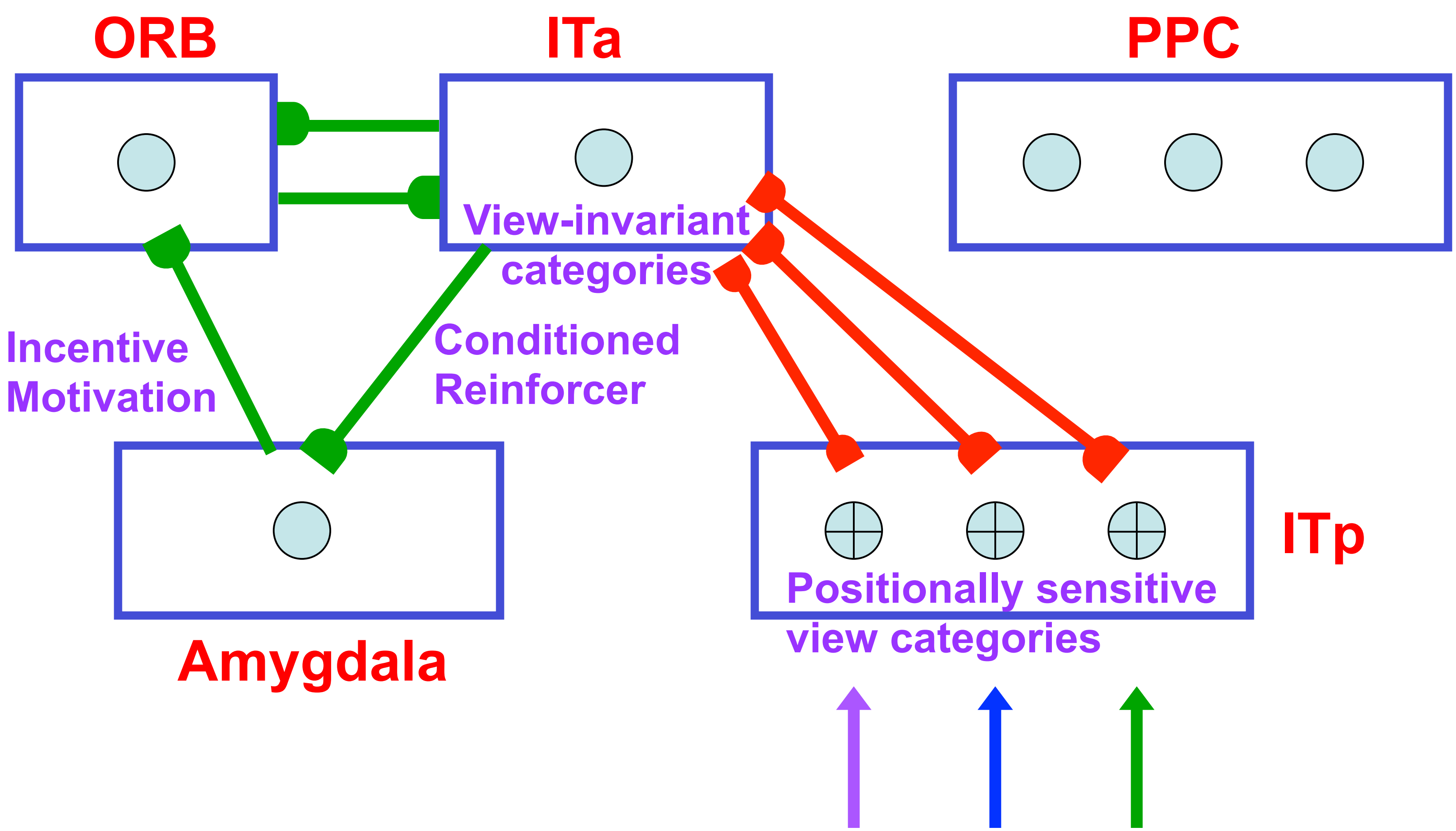


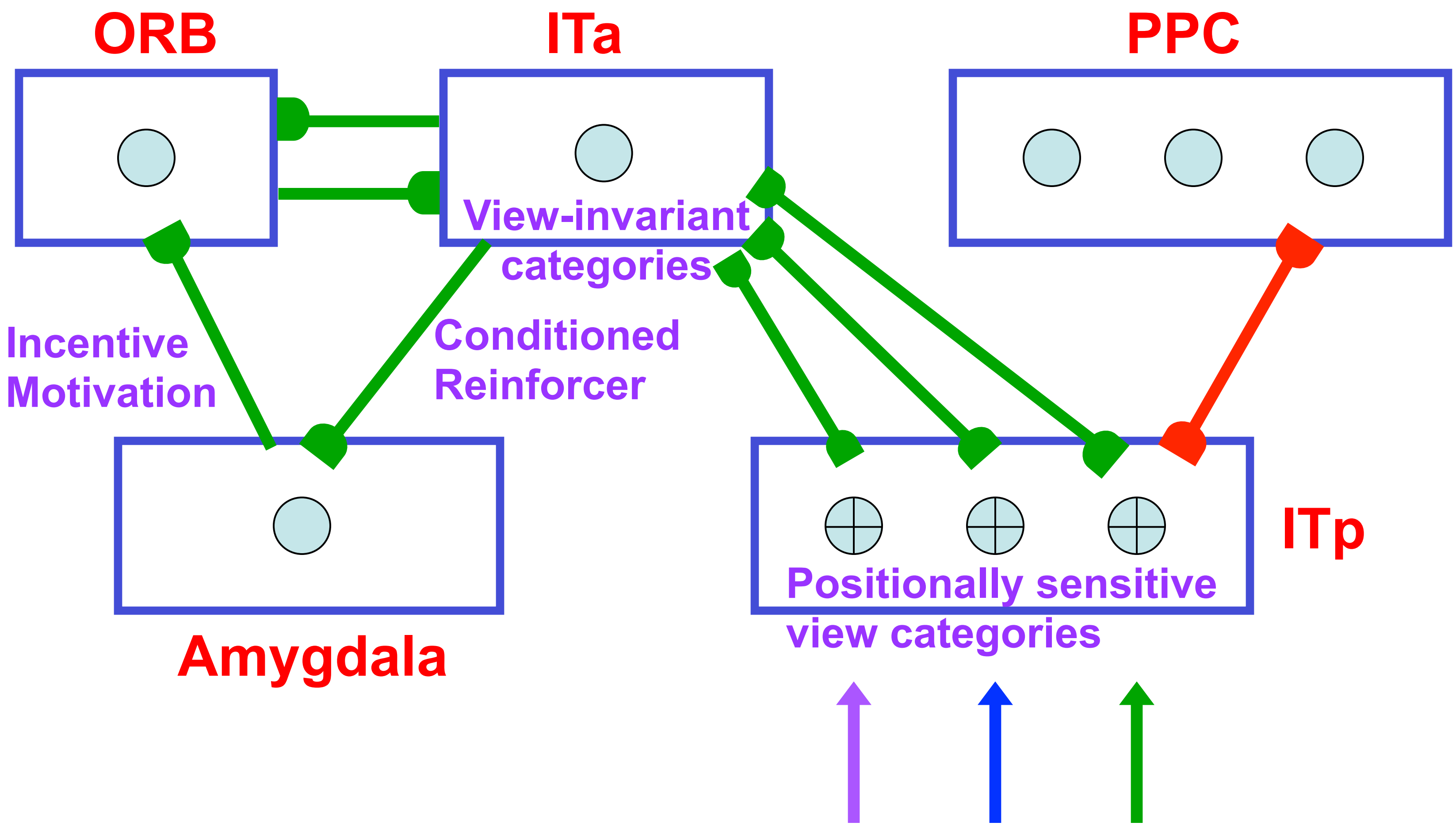
MULTIPLE BRAIN REGIONS GUIDE WALDO SEARCH FROM SCENIC INPUT TO WALDO DISCOVERY

The amplified ITa cells send
top-down priming signals to ITp

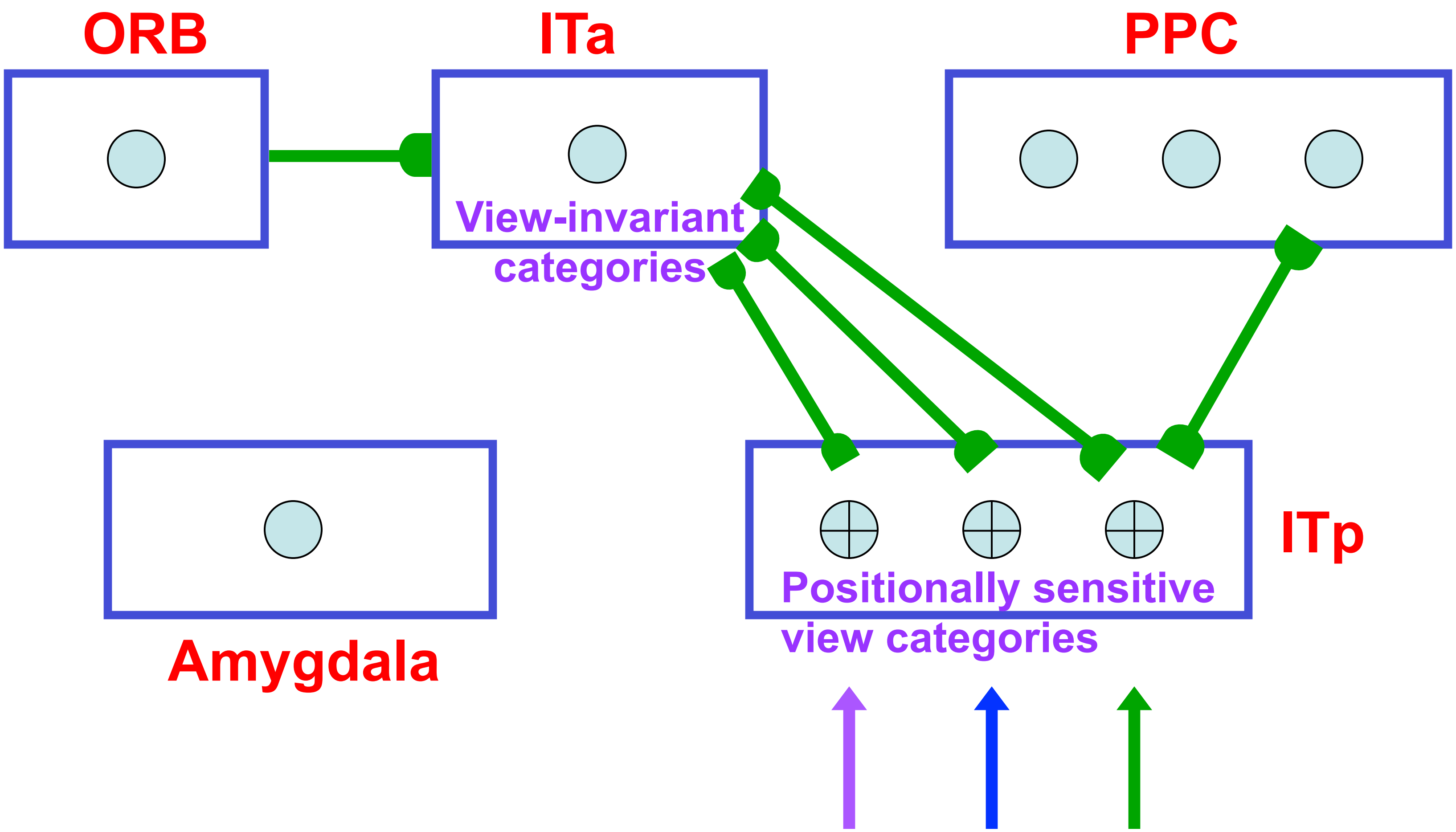


MULTIPLE BRAIN REGIONS GUIDE WALDO SEARCH FROM SCENIC INPUT TO WALDO DISCOVERY

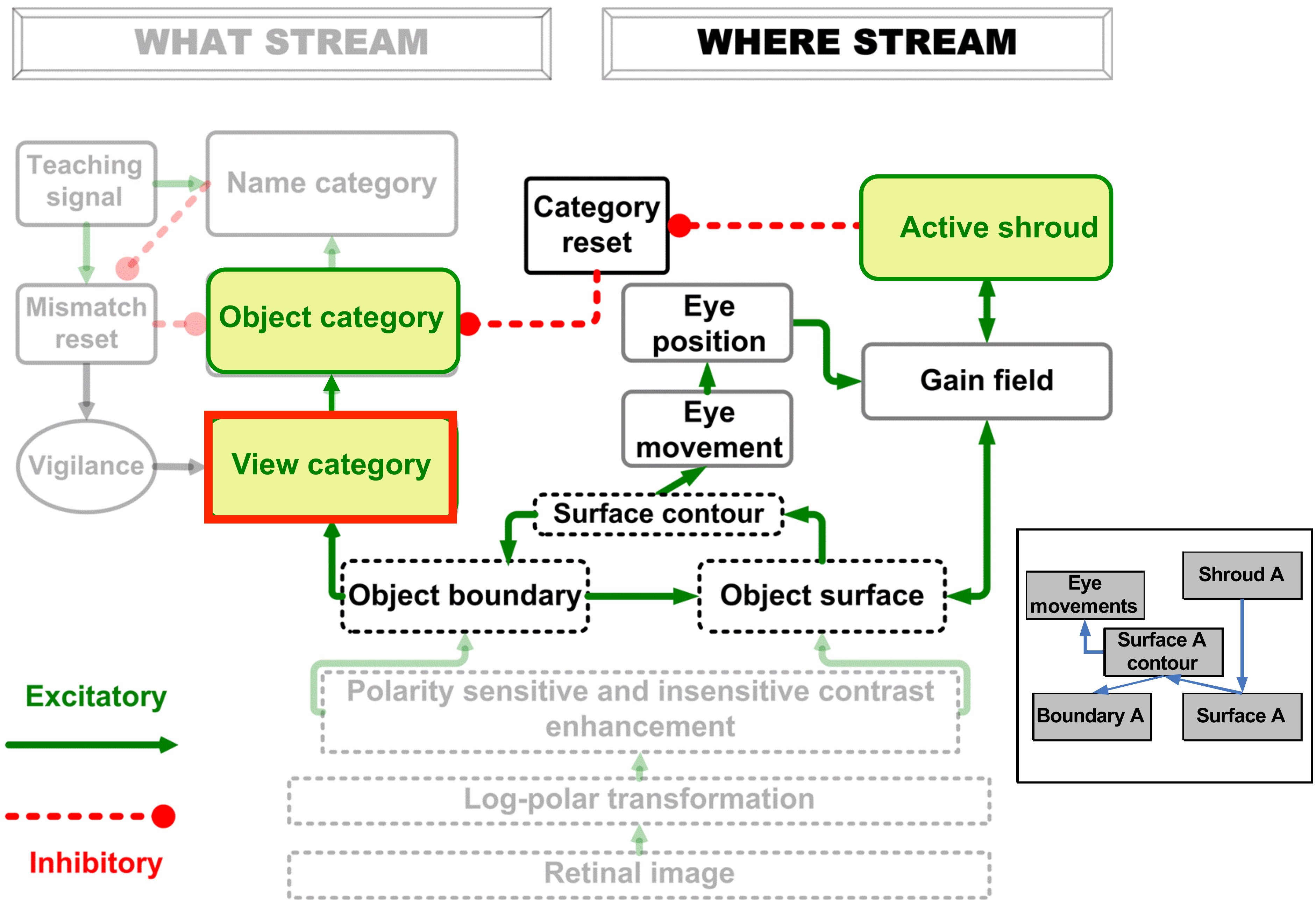
The selectively amplified ITp cells
send amplified signals to PPC
PPC elicits an eye movement to Waldo



MULTIPLE BRAIN REGIONS GUIDE WALDO SEARCH FROM COGNITIVE PRIME TO WALDO DISCOVERY



HOW ARE VIEW CATEGORIES LEARNED?



MORE COMPLEMENTARY COMPUTING…

COGNITION

How do we remember stuff for 50 years?!

CREATIVE DISCOVERY OF CAUSAL RELATIONS IN A CHANGING WORLD

Why are we

symbol forming

intentional

attentional

learning

beings?

HOW ARE VIEW CATEGORIES LEARNED?

ADAPTIVE RESONANCE THEORY
ART

Grossberg (1976)

A unifying theme:

Stability-Plasticity Dilemma

How can learning continue into adulthood without causing catastrophic forgetting?

How can we LEARN quickly without being forced to FORGET just as quickly?

e.g., why learning your faces does not force me to forget faces of my family and friends!

LEARNING VS. FORGETTING

We can LEARN stuff quickly without being forced to FORGET other important stuff just as quickly!

Learned events are bound together into coherent context-sensitive representations

A big accomplishment of our minds

Emergence of self or mind

Personality

Relationships

Family

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SEVERAL KINDS OF LEARNING AND MEMORY NEEDED FOR THE EMERGENCE OF SELF

Recognition	Identify	What
Reinforcement	Evaluate	Why
Timing	Synchronize	When
Spatial	Locate	Where
Motor	Act	How

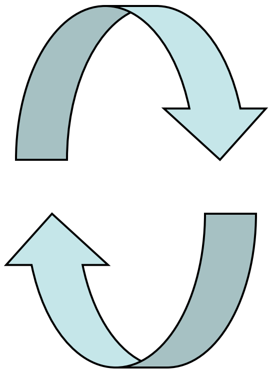
…and they Interact!

ART MAIN IDEA

Top-down attentive feedback
encodes
learned expectations
that
SELF-STABILIZE LEARNING
in response to
arbitrary temporal sequences
of input spatial patterns in
real time

Attentive Information Processing

FAST



Learning and Memory

SLOW

COGNITIVE LEARNING CYCLE

A dynamic cycle of

RESONANCE

and

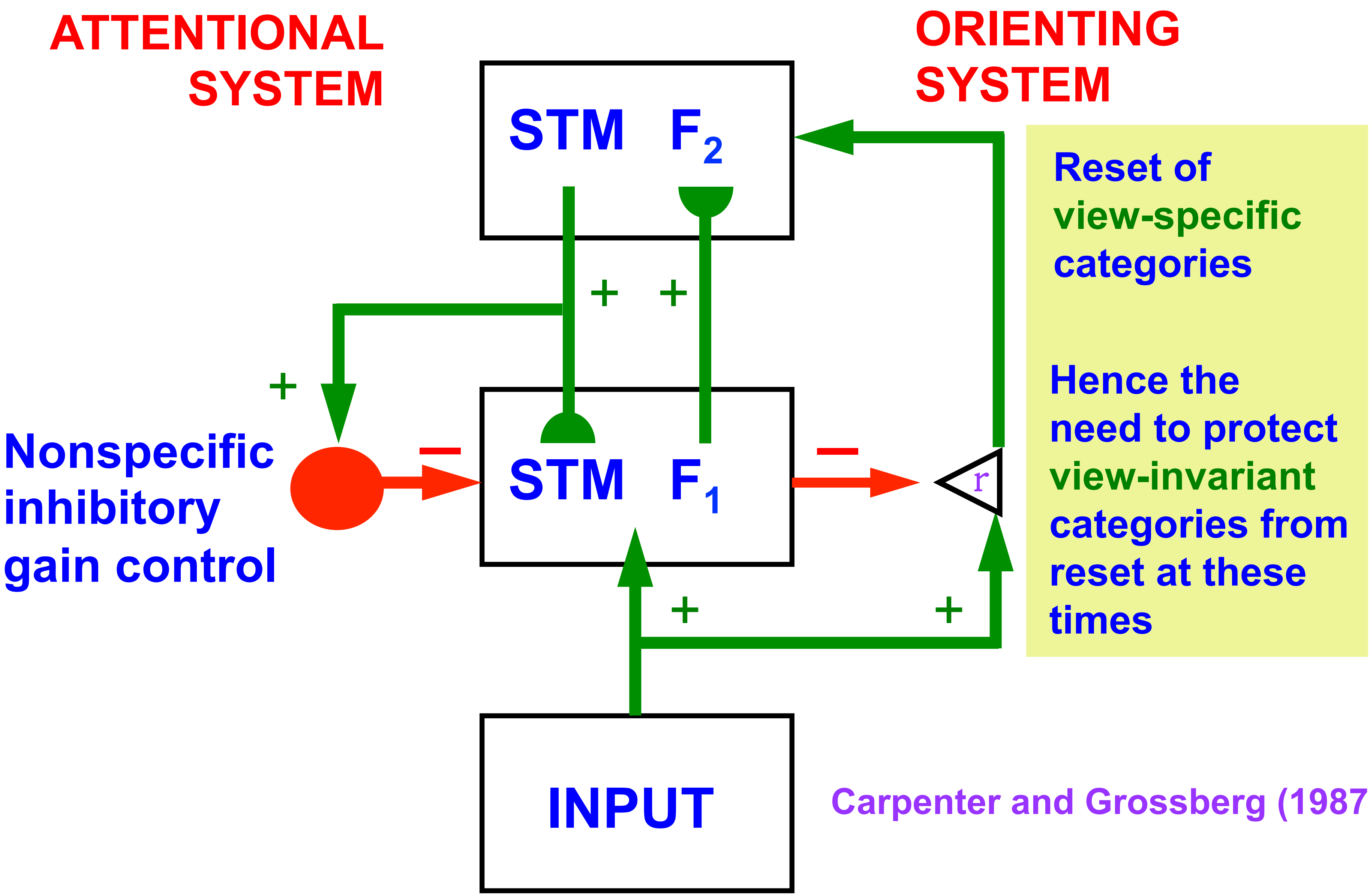
RESET

As objects are learned, search automatically disengages
direct access to globally best-matching category

Mathematical proof in: Carpenter & Grossberg, *CVGIP*, 1987

Explains how we can quickly recognize familiar objects even if, as we get older, we store enormous numbers of memories

ART VIEW CATEGORIES GET *RESET* WHEN THE OBJECT VIEW CHANGES SUFFICIENTLY



Carpenter and Grossberg (1987)

LEARN CONCRETE OR ABSTRACT CATEGORIES?
TASK-SENSITIVE VIGILANCE CONTROL

How do our cognitive categories learn

to represent uniquely different experiences?

How do our brains learn CONCRETE knowledge for some

tasks and ABSTRACT knowledge for others?

High Vigilance – Narrow Categories; CONCRETE

Mom's face

Low Vigilance – Broad Categories; ABSTRACT

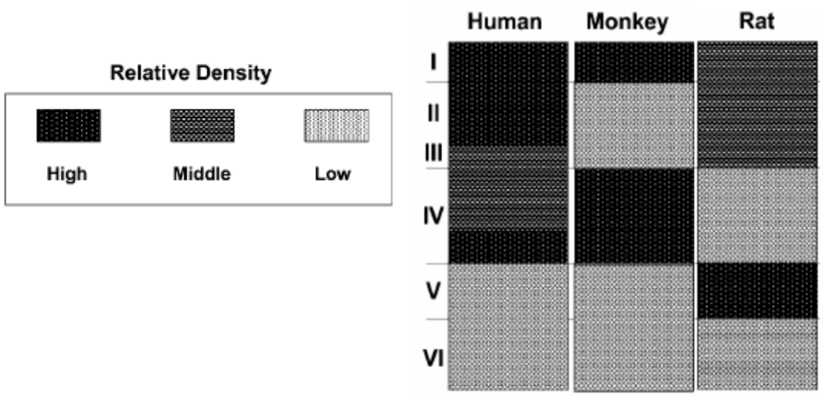
A face

VIGILANCE CONTROL:
MISMATCH-MEDIATED ACETYLCHOLINE RELEASE

Acetylcholine (Ach) regulation by NONSPECIFIC THALAMIC NUCLEI via NUCLEUS BASALIS OF MEYNERT reduces AHP in layer 5

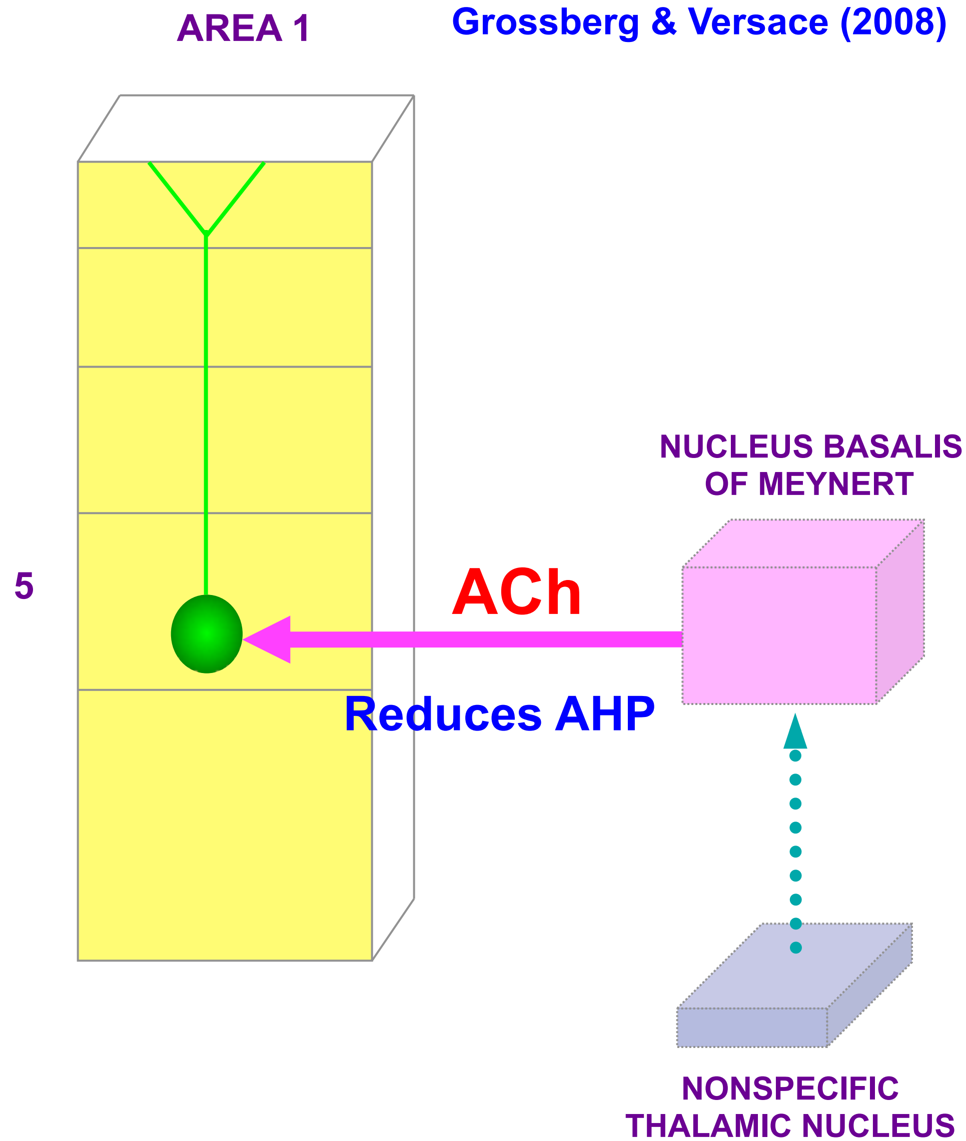
Ach thereby facilitates RESET (compare ART VIGILANCE control)

HIGH Vigilance ~ Sharp Code
LOW Vigilance ~ Coarse Code



CHOLINERGIC DENSITY AXONS IN V1 AND HOMOLOGS
Gu (2003)

Grossberg & Versace (2008)



WHEN RECOGNITION LEARNING FAILS

Clarifies aspects of major mental diseases

AUTISM: hyperspecific learning

Breakdown in vigilance mechanism that determines how we learn both abstract and concrete knowledge

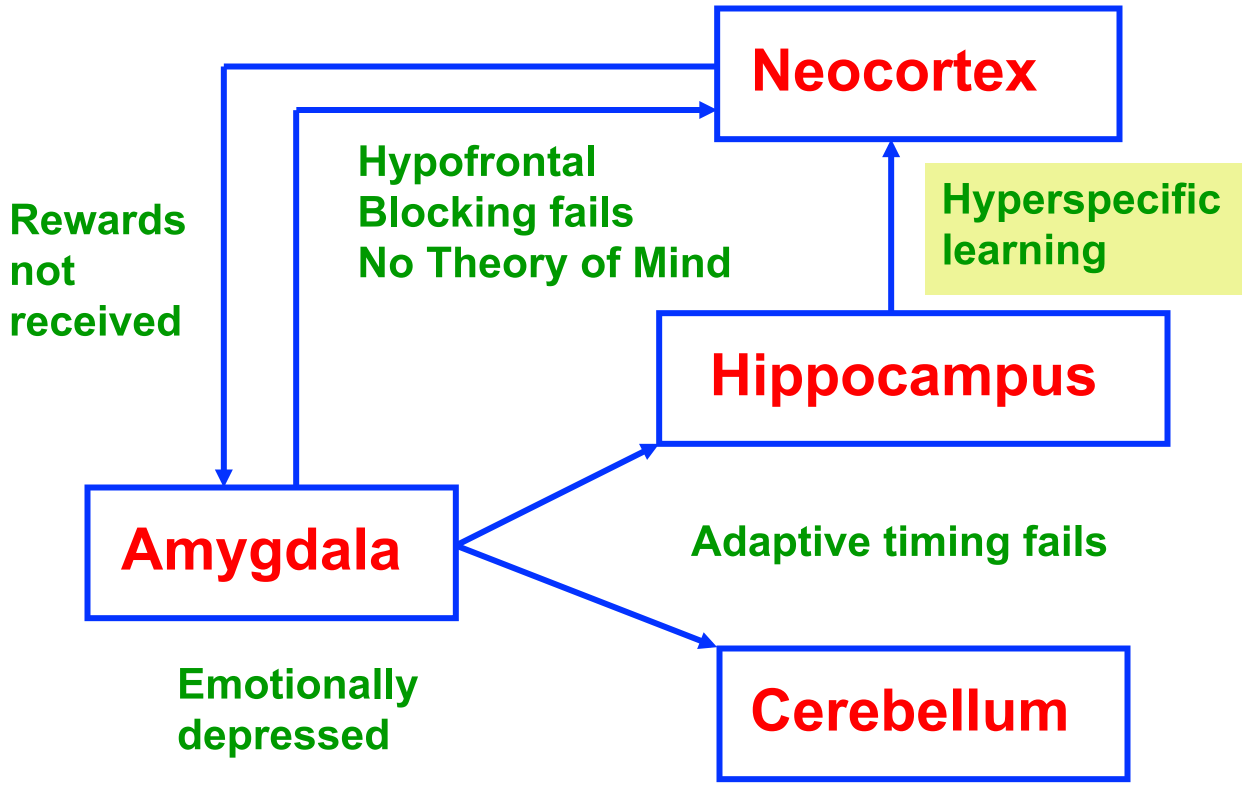
SCHIZOPHRENIA: hallucinations

Breakdown in mechanism that controls how we pay attention to events in the world

Problems due to IMBALANCES in COMPLEMENTARY brain mechanisms

MULTIPLE PROBLEMS DURING AUTISM

Grossberg and Seidmann (2006, Psychological Review)



Experimental tests:

Vladusich, Lafe, Kim, Tager-Flusberg, & Grossberg., Autism Research, 2009, 3, 226-236

Church,…& Mercado, Psychonomic Bulletin & Review, , 2010, 17, 862-868

ABSTRACT

How does an infant learn through visual experience to imitate actions of adult teachers, despite the fact that the infant and adult view one another and the world from different perspectives? To accomplish this, an infant needs to learn how to share joint attention with adult teachers and to follow their gaze towards valued goal objects. The infant also needs to be capable of view-invariant object learning and recognition whereby it can carry out goal-directed behaviors, such as the use of tools, using different object views than the ones that its teachers use. Such capabilities are often attributed to ‘‘mirror neurons’’. This attribution does not, however, explain the brain processes whereby these competences arise. This article describes the CRIB (Circular Reactions for Imitative Behavior) neural model of how the brain achieves these goals through INTER-PERSONAL CIRCULAR REACTIONS. Inter-personal circular reactions generalize the INTRA-PERSONAL CIRCULAR REACTIONS of Piaget, which clarify how infants learn from their own babbled arm movements and reactive eye movements how to carry out volitional reaches, with or without tools, towards valued goal objects. The article proposes how intra-personal circular reactions create a foundation for inter-personal circular reactions when infants and other learners interact with external teachers in space. Both types of circular reactions involve learned coordinate transformations between body-centered arm movement commands and retinotopic visual feedback, and coordination of processes within and between the What and Where cortical processing streams. Specific breakdowns of model processes generate formal symptoms similar to clinical symptoms of autism

VIGILANCE DATA IN INFEROTEMPORAL CORTEX

RECEPTIVE FIELD SELECTIVITY MUST BE LEARNED

Some cells respond selectively to particular views of particular faces

Other cells respond to broader features of an animal's environment

Desimone, Gross, Perrett, …

EASY vs. DIFFICULT DISCRIMINATIONS: VIGILANCE!

"In the difficult condition the animals adopted a stricter internal criterion for discriminating matching from non-matching stimuli…The animal's internal representations of the stimuli were better separated … increased effort appeared to cause enhancement of the responses and sharpened selectivity for attended stimuli…"

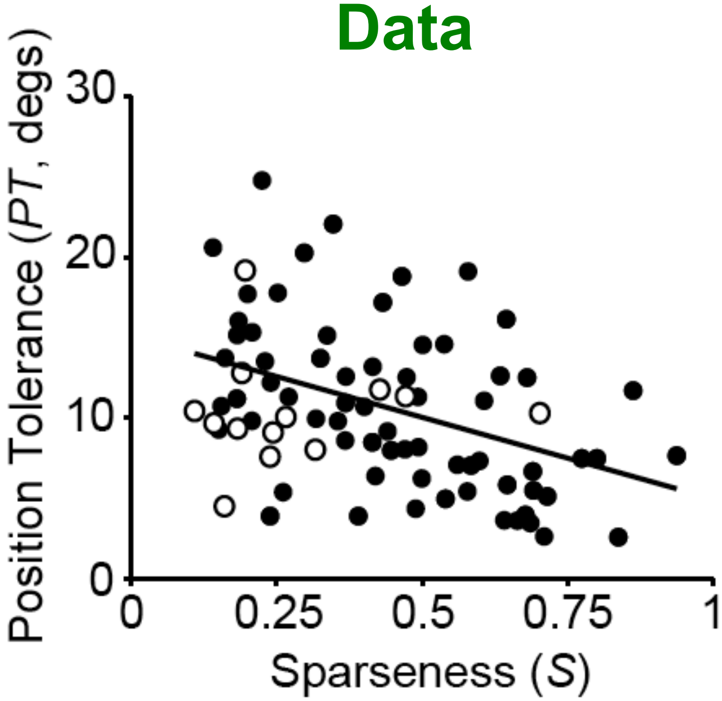
Spitzer, Desimone, and Moran (1988)

TRADEOFF IN IT CELL RESPONSE PROPERTIES

Inferotemporal cortex cells with greater position invariance respond less selectively to natural objects Zoccolan, Kouh, Poggio, & DiCarlo (2007)

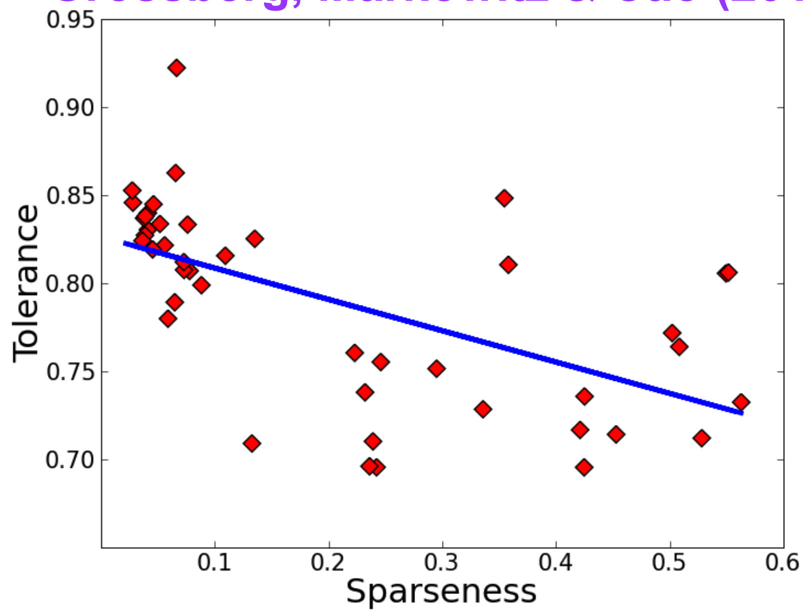
Invariance~tolerance
Selectivity~sparseness

Data



Model

Grossberg, Markowitz & Cao (2010)



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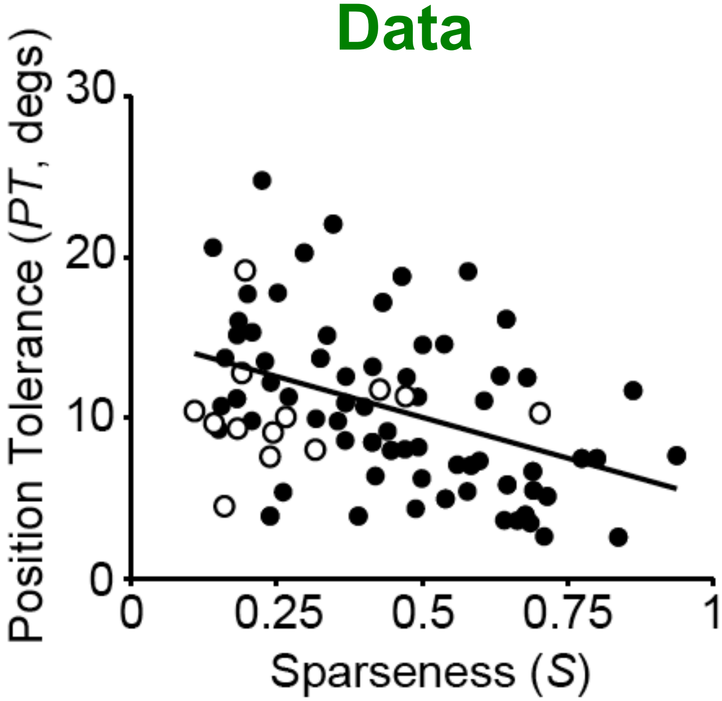

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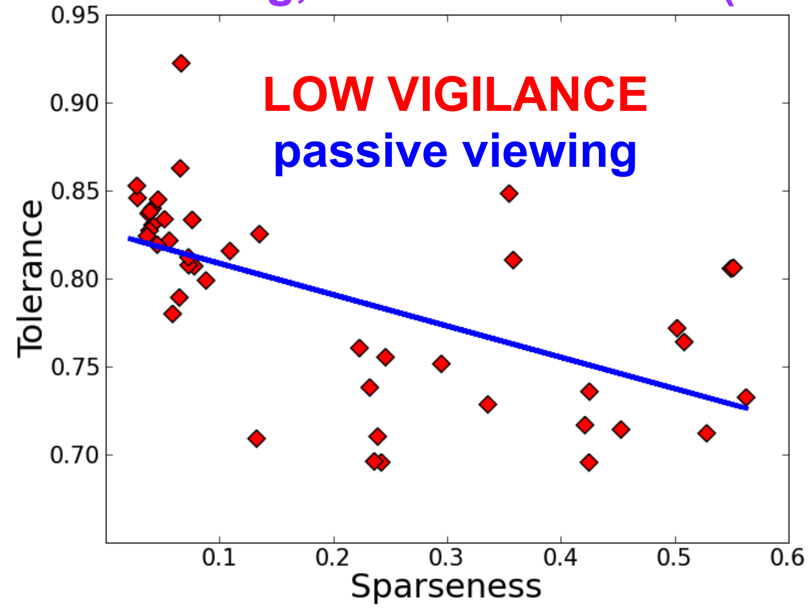
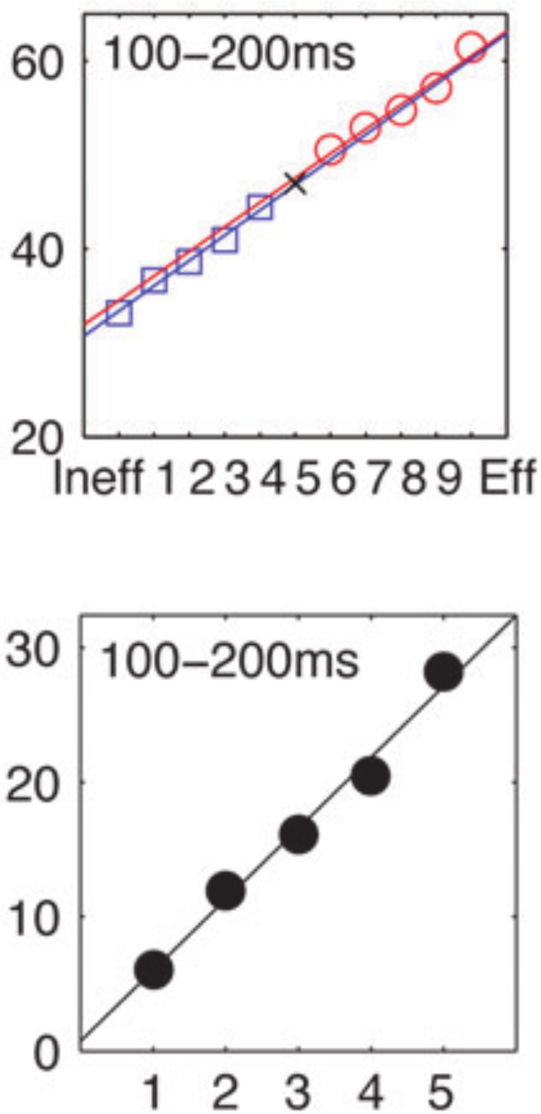


IT RESPONSES TO IMAGE MORPHS

Akrami, Liu, Treves, & Jagadeesh (2009)

Data



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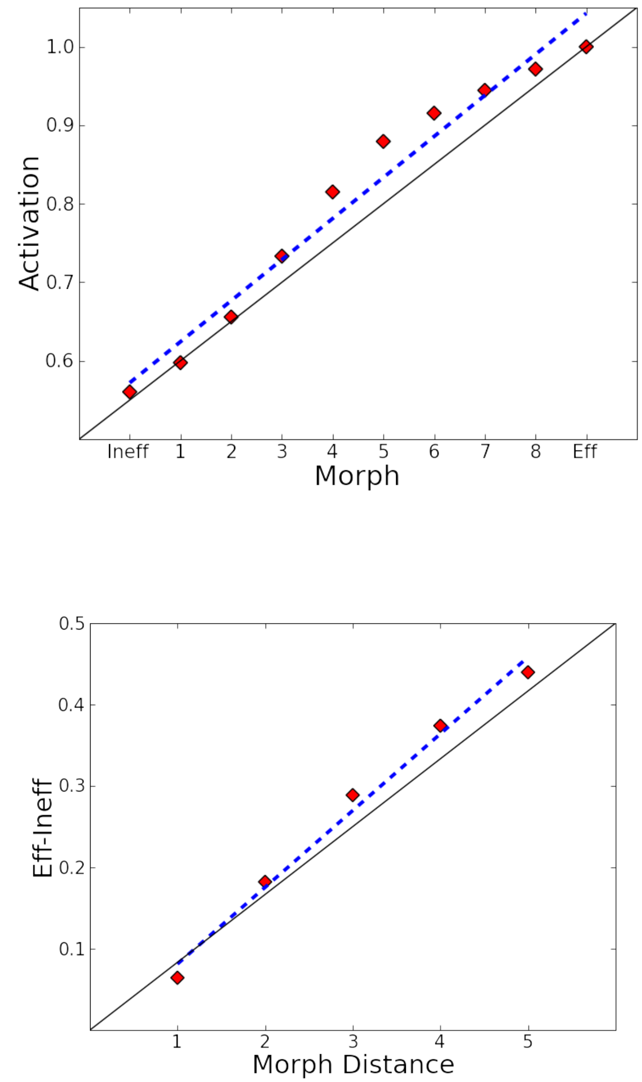

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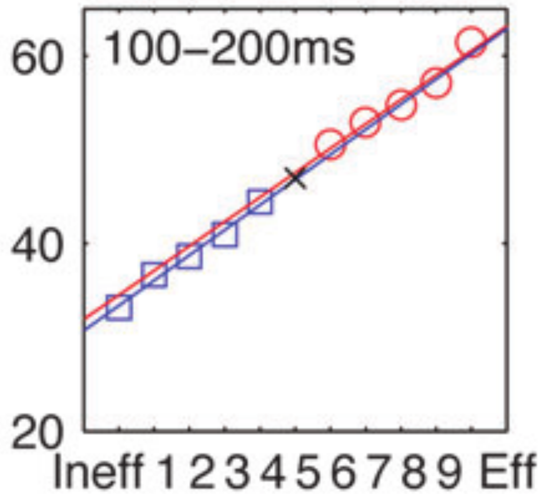

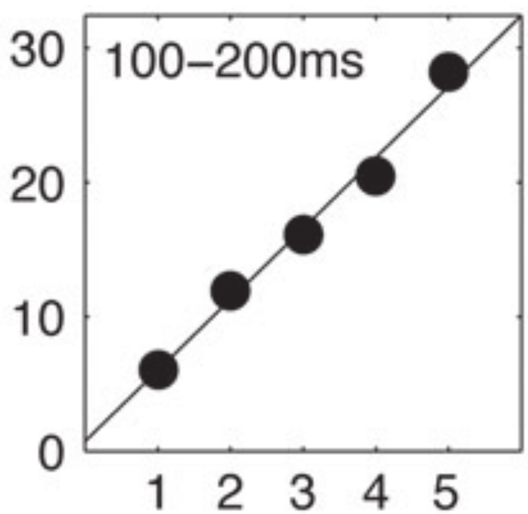

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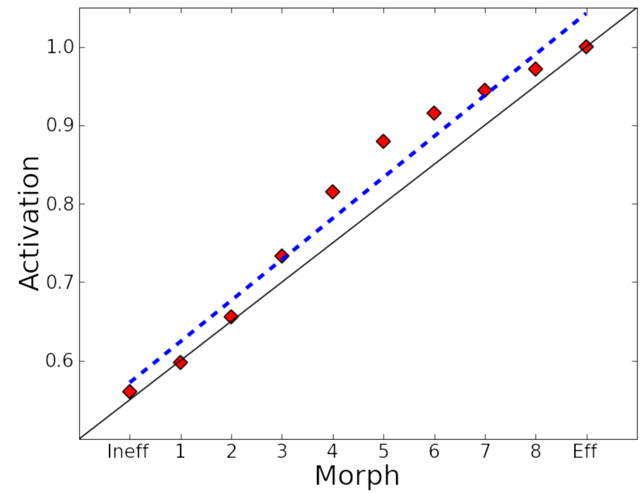
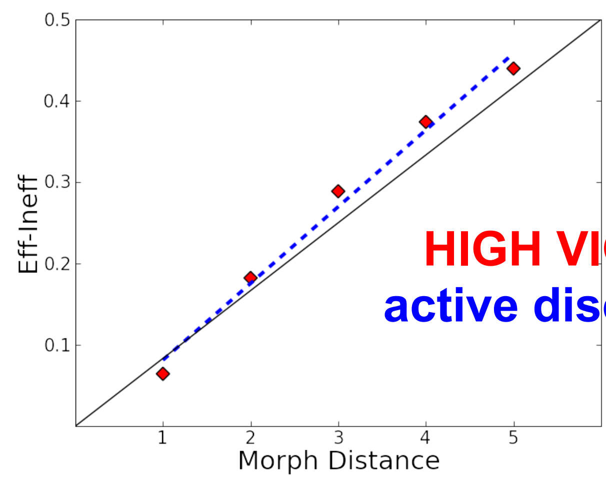




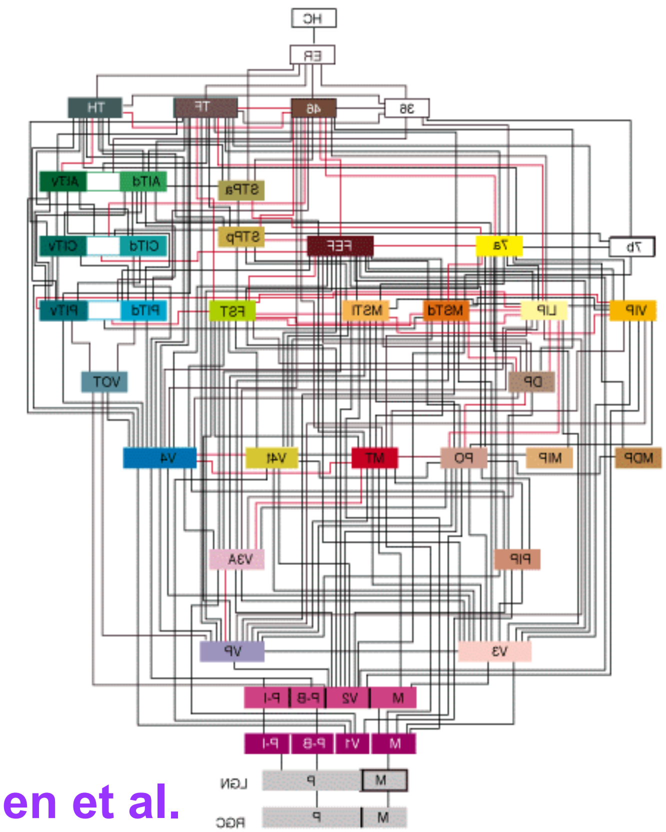
HIGH VIGILANCE

active discrimination

HOW TO DESIGN LARGE-SCALE NEURAL ARCHITECTURES FOR AUTONOMOUS BEHAVIORAL CONTROL?

Explain multiple behavioral data bases that place convergent design constraints on overlapping combinations of brain areas

ARTSCAN and pARTSCAN
ARTSCENE Search
lisTELOS



van Essen et al.

COMPLEMENTARY brain interactions are beginning to explain why the brain looks and works the way that it does