

# Making Robots that Really Feel

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**J. Kevin O'Regan  
Laboratoire Psychologie de la Perception  
CNRS – Université Paris Descartes – Paris**

# Nao, the first robot able to feel emotions and form bonds with humans that look after it

By DAILY MAIL REPORTER

13 August 2010

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Nao have been created through modelling the early attachment process that human and chimpanzee infants undergo when they are very young.

It forms part of a European project called FEELIX Growing, that is being led by Lola Canamero, a computer scientist at the University of Hertfordshire.

'This behaviour is modelled on what a young child does,' said Dr Cañamero. 'This is also very similar to the way chimpanzees and other non-human primates develop affective bonds with their caregivers.'

Nao is programmed to become particularly attached to an individual who interacts with the robot in a certain way that helps it to learn.



*University of Hertfordshire researcher Dr Lola Canamero with Nao, a robot that can show its emotions and form a bond with humans*

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*University of Hertfordshire researcher Dr Lola Canamero with Nao, a robot that can show its emotions and form a bond with humans*

# Most people are wrong!

There is nothing to stop robots from having real feels!

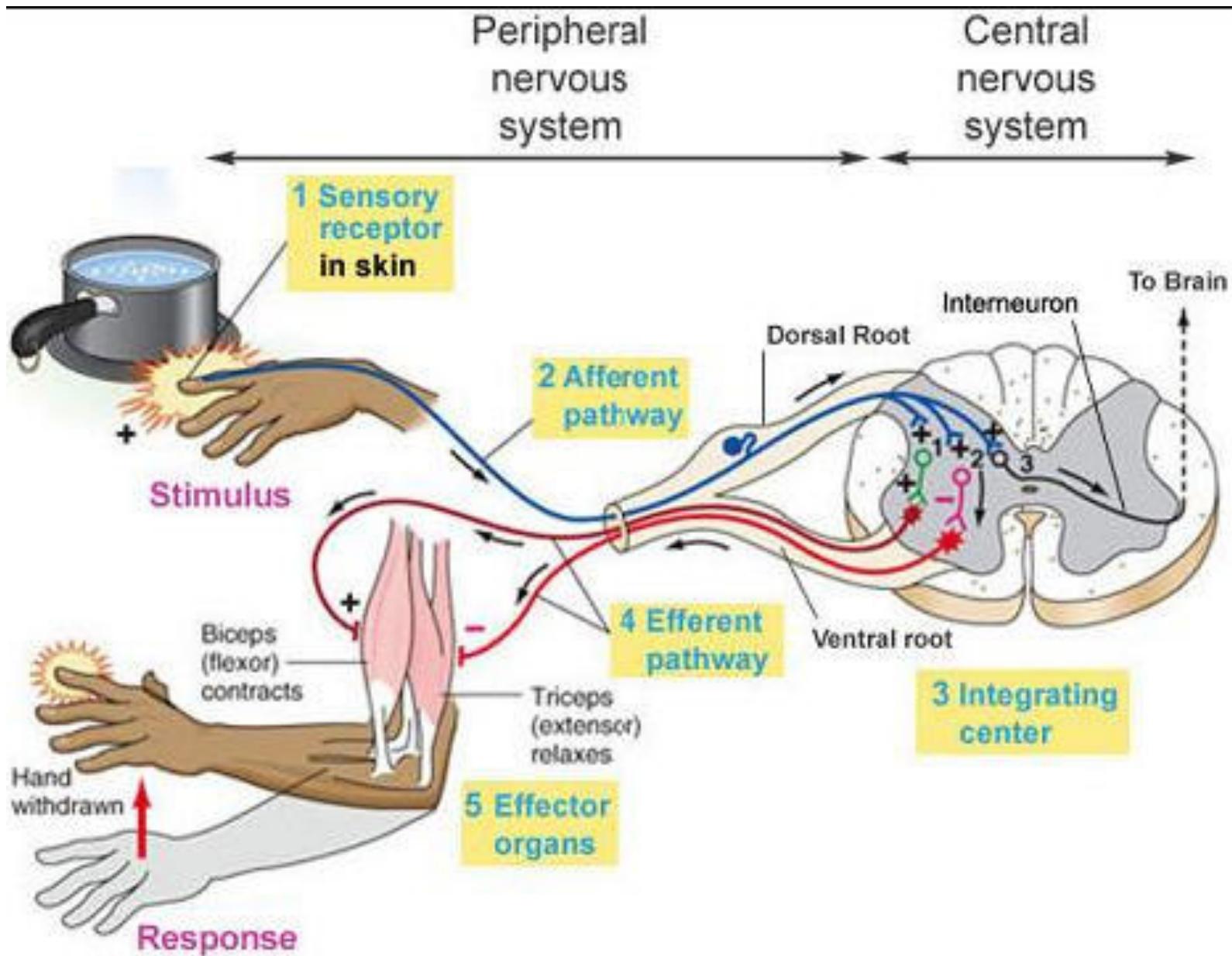
# Why most people think there's a problem

How to make a robot that really feels something

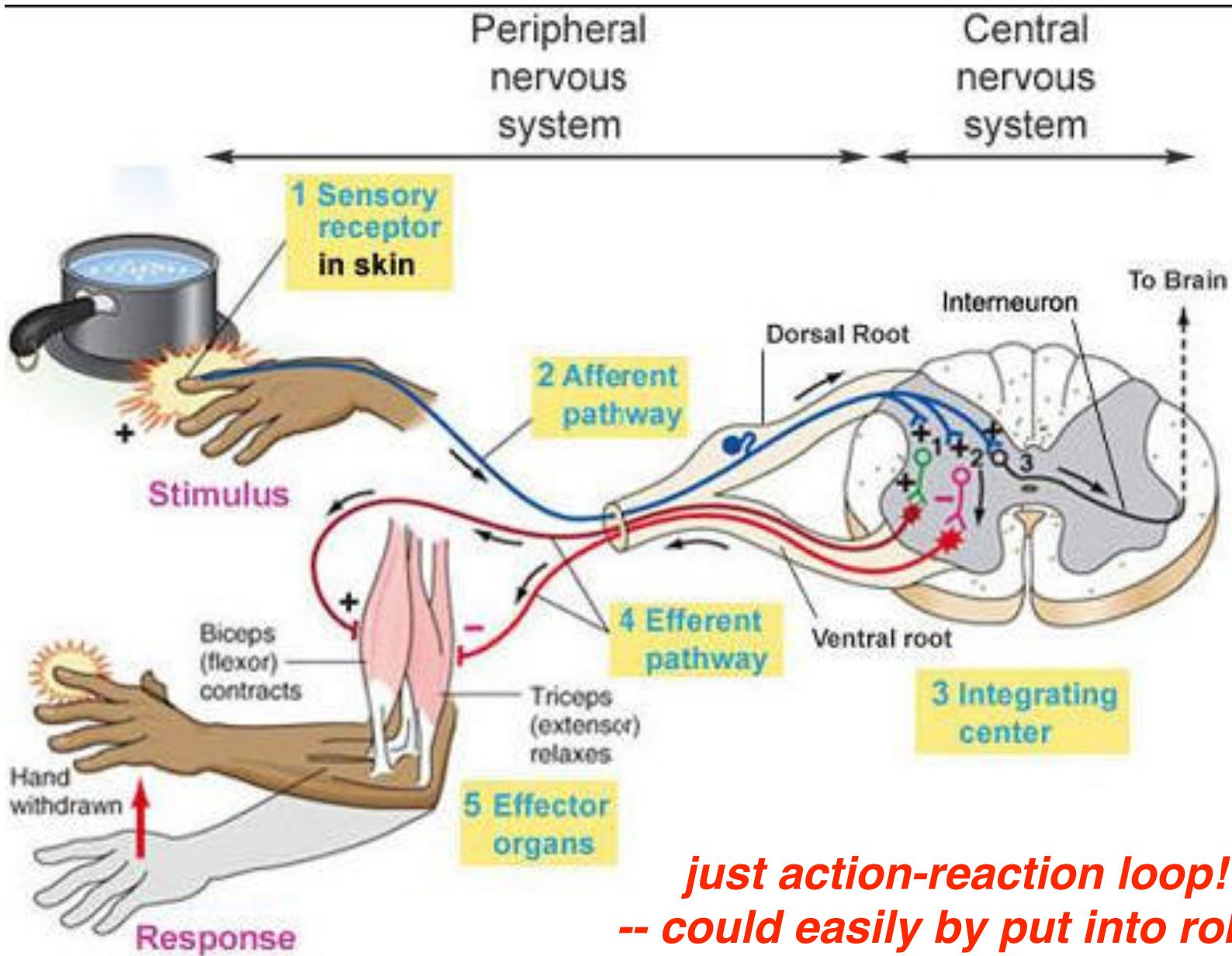
ex: try to build pain into a robot

look at how pain occurs in humans

# Pain circuits in humans

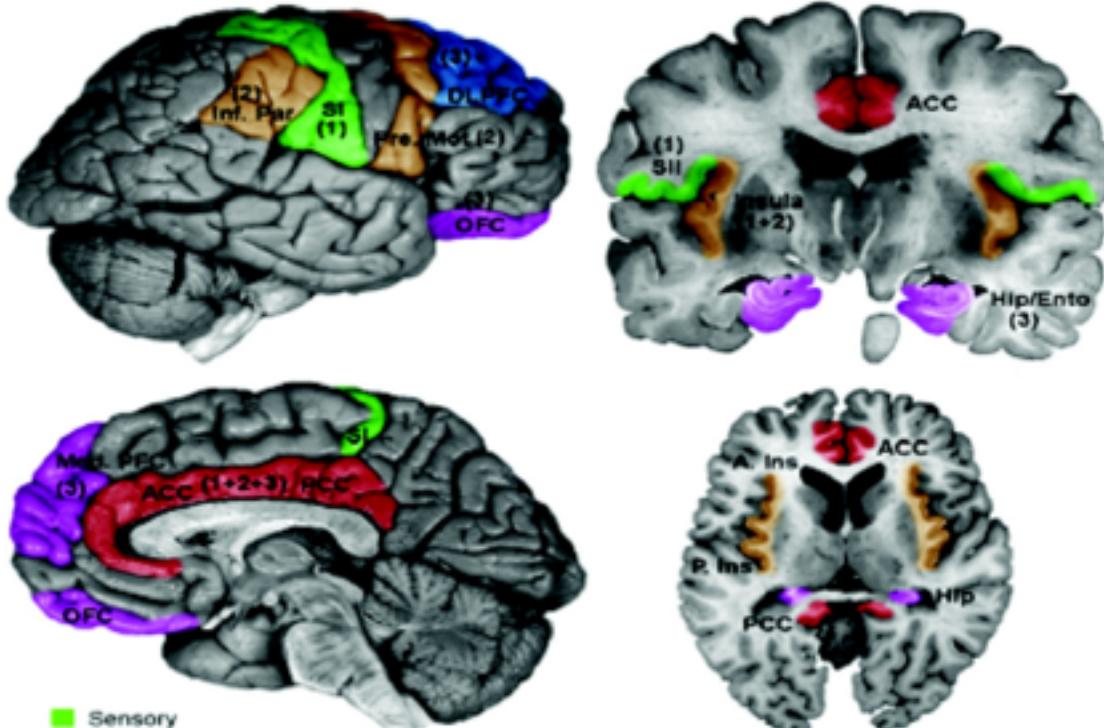


# Pain circuits in humans



*just action-reaction loop!  
-- could easily be put into robot*

# Brain Centers involved in pain sensation



■ Sensory

■ Affective

■ Cognitive

■ = ■ + ■

■ = ■ + ■

(1) Early Identification

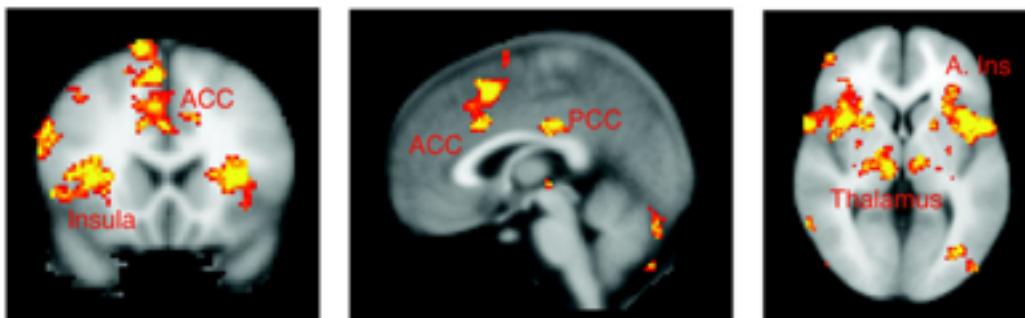
(2) Recognition & Immediate Reaction

(3) Evaluation & Sustained Behaviour

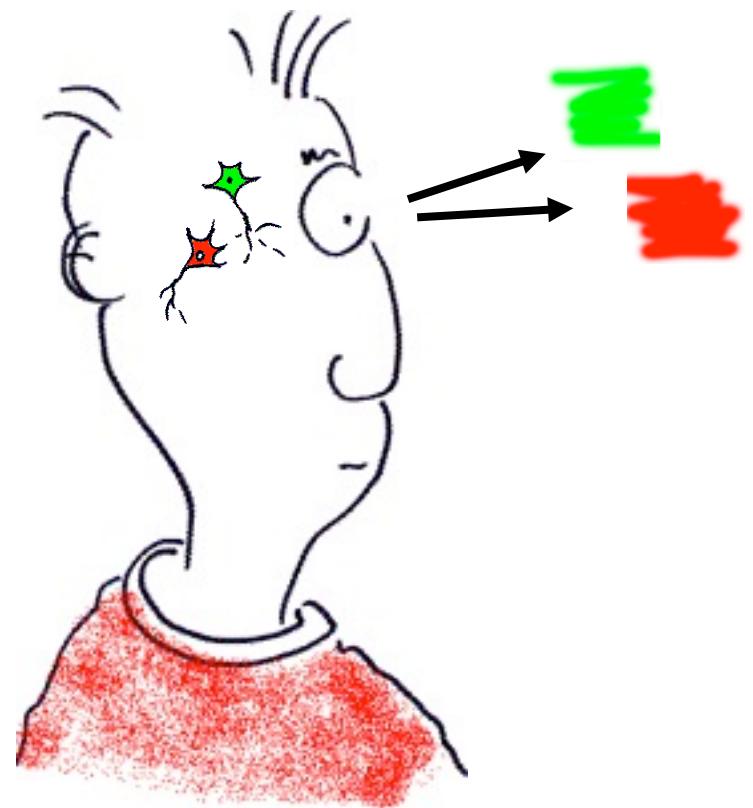
B. Example of functional MRI response to painful stimulation.

chemical pathways:

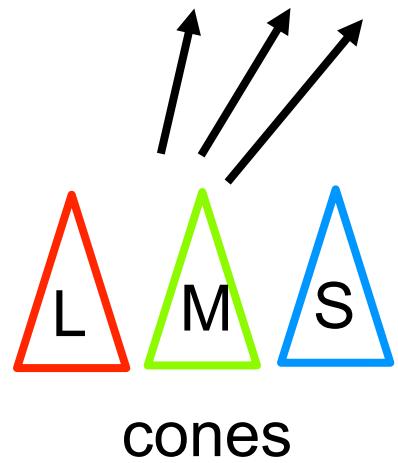
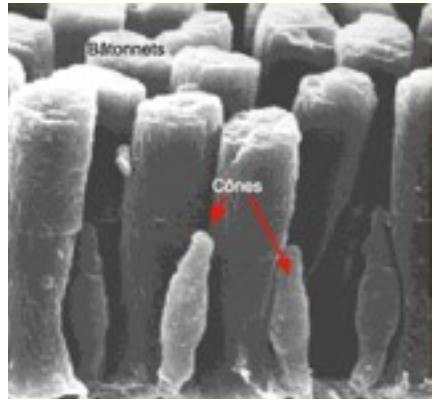
- serotonin
- norepinephrine



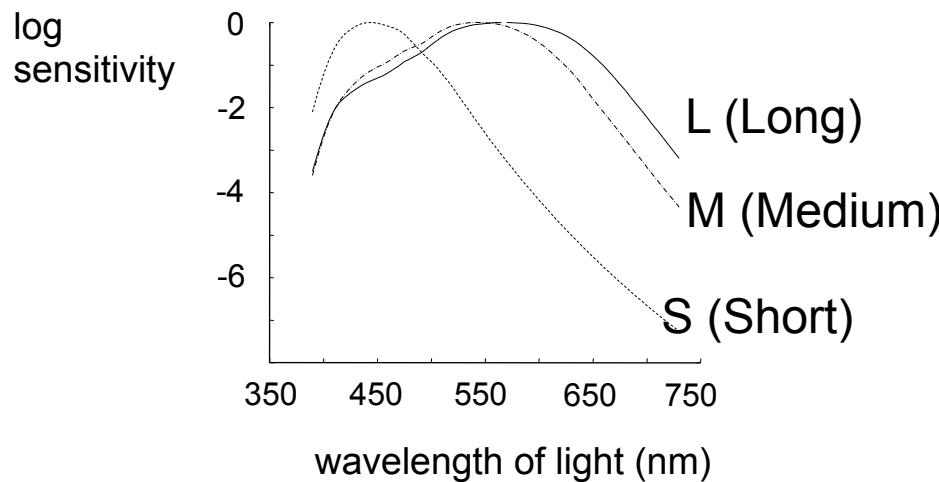
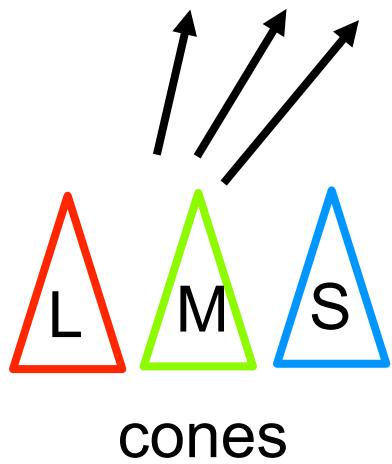
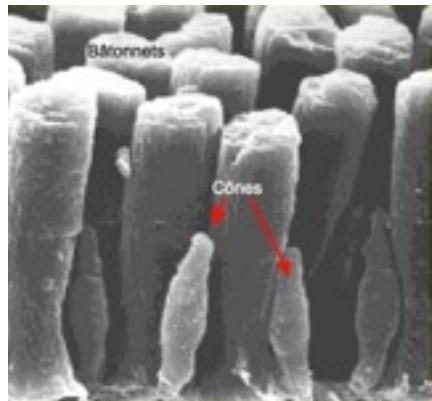
# How to generate the redness of red?



# Human photoreceptors (cones)

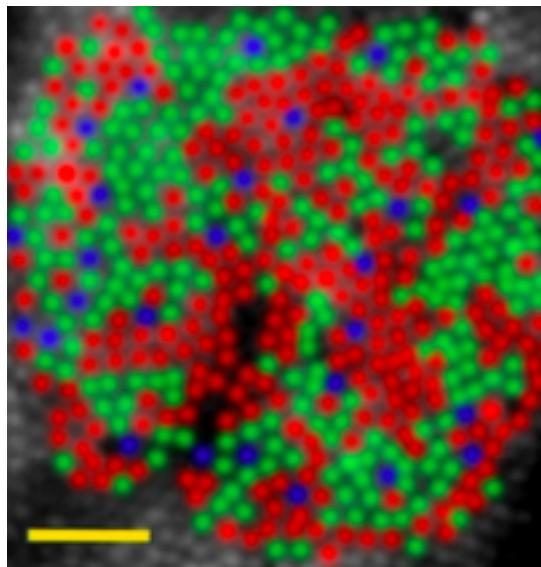
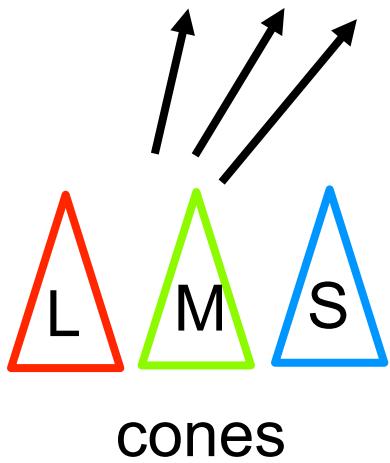
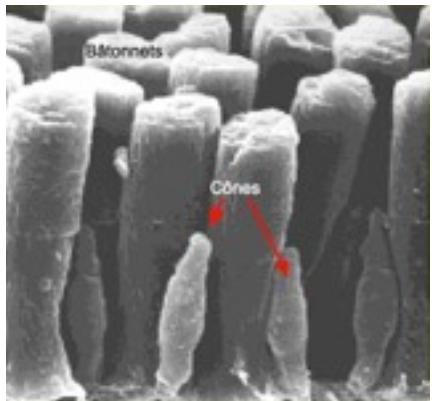


# Human photoreceptors (cones)

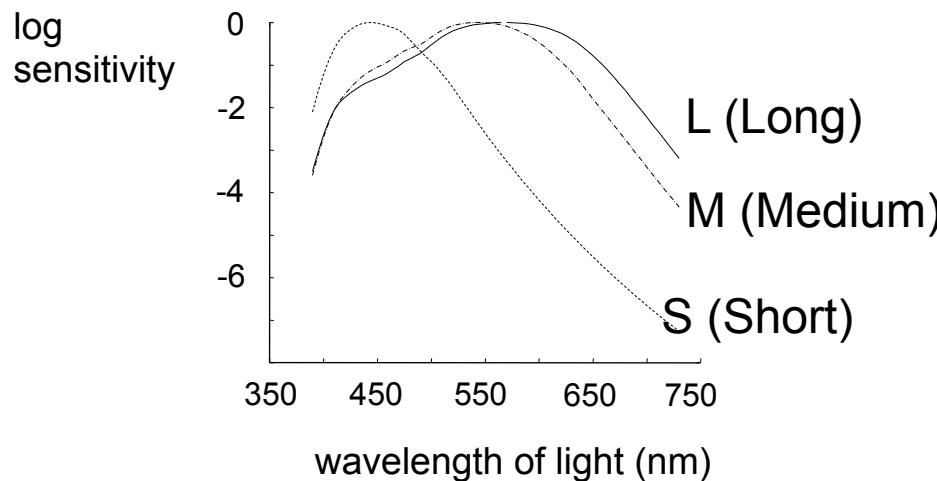


Stockman & Sharpe (2000)

# Human photoreceptors (cones)

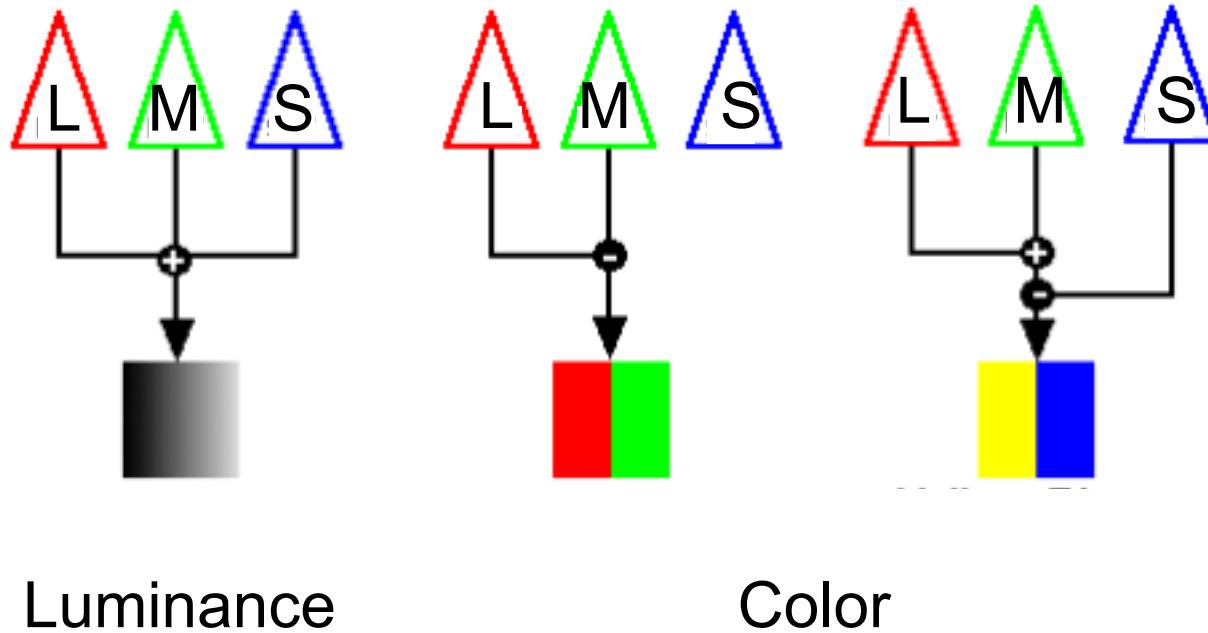


densely packed in central retina



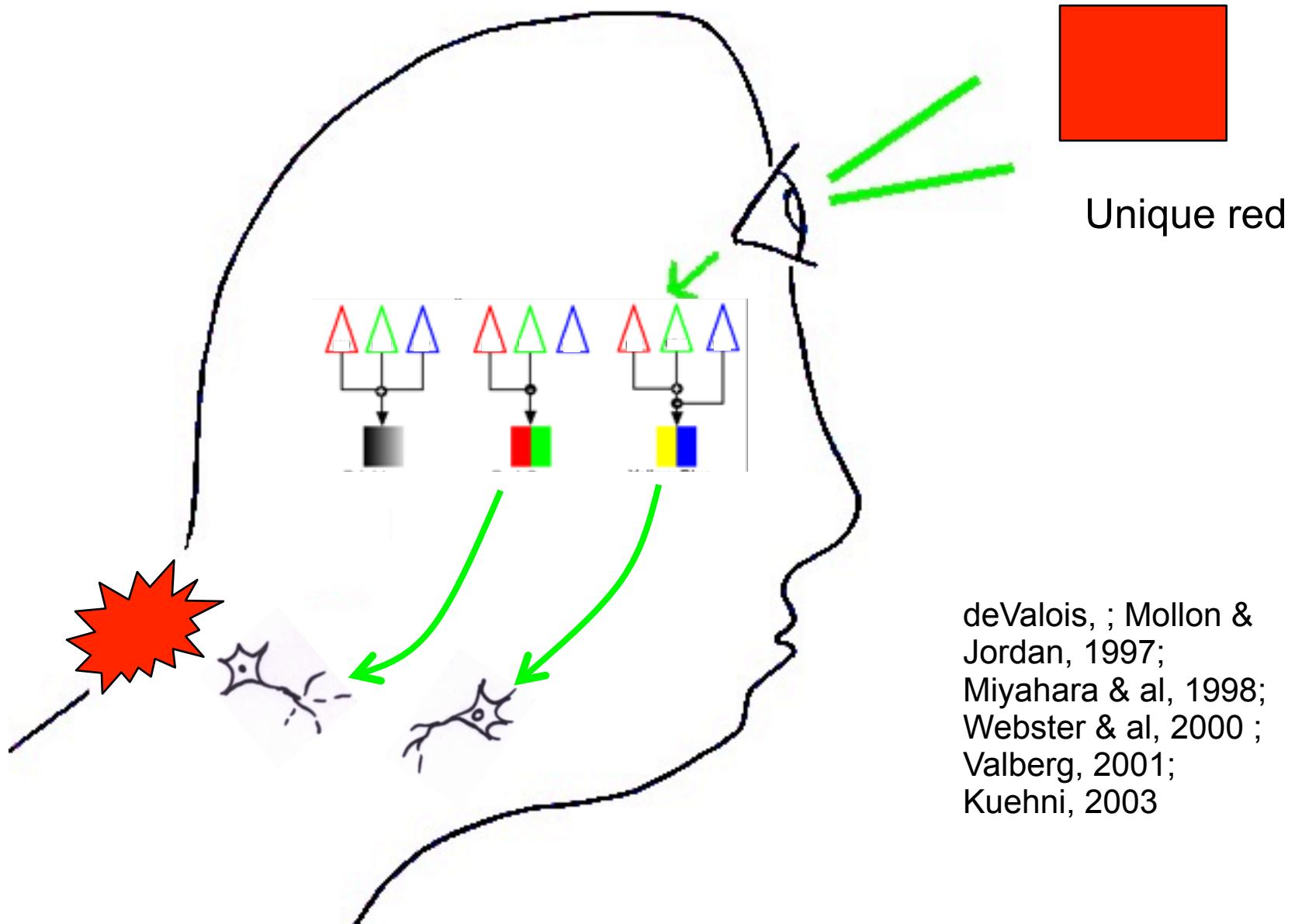
Stockman & Sharpe (2000)

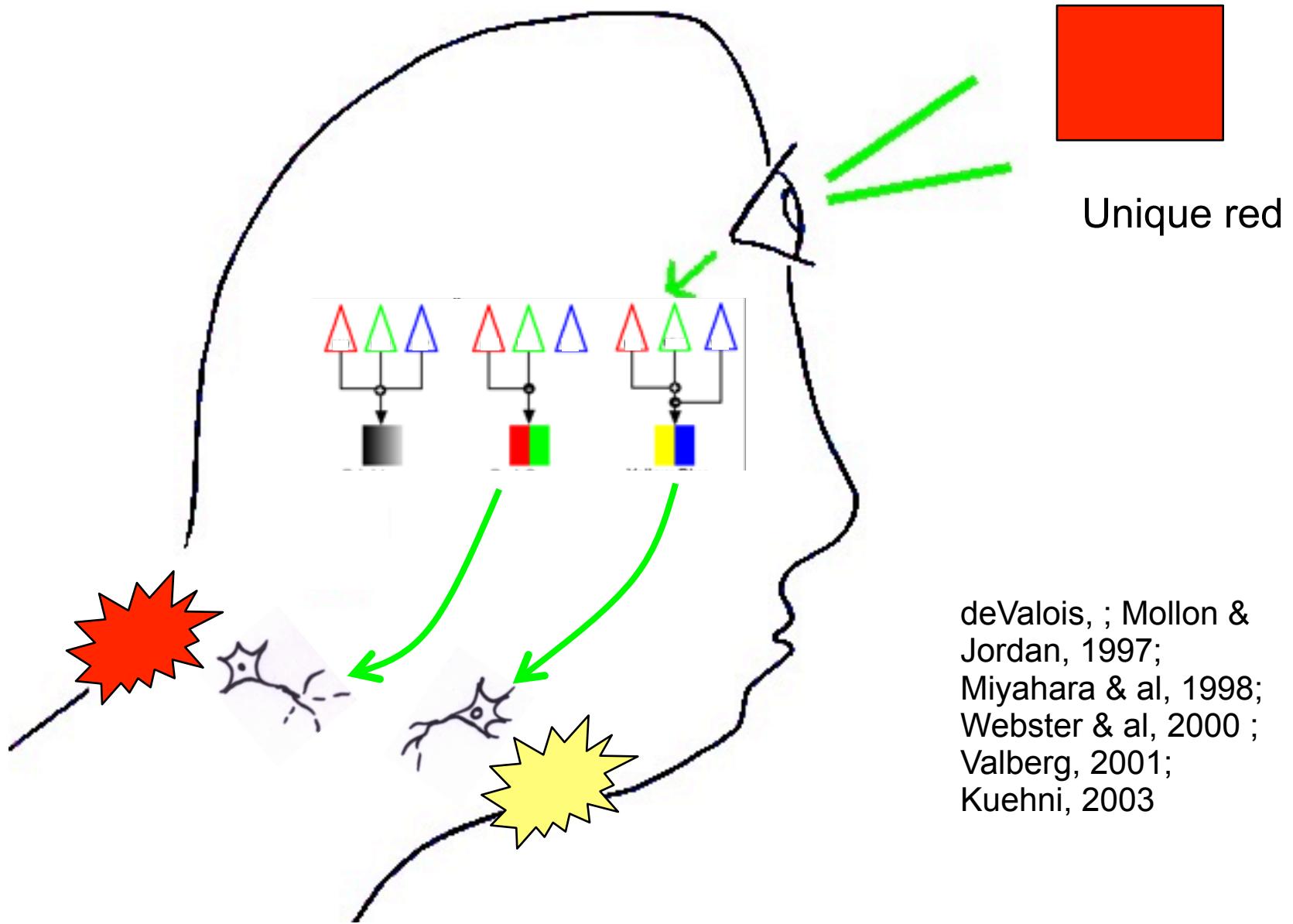
# Color Opponency

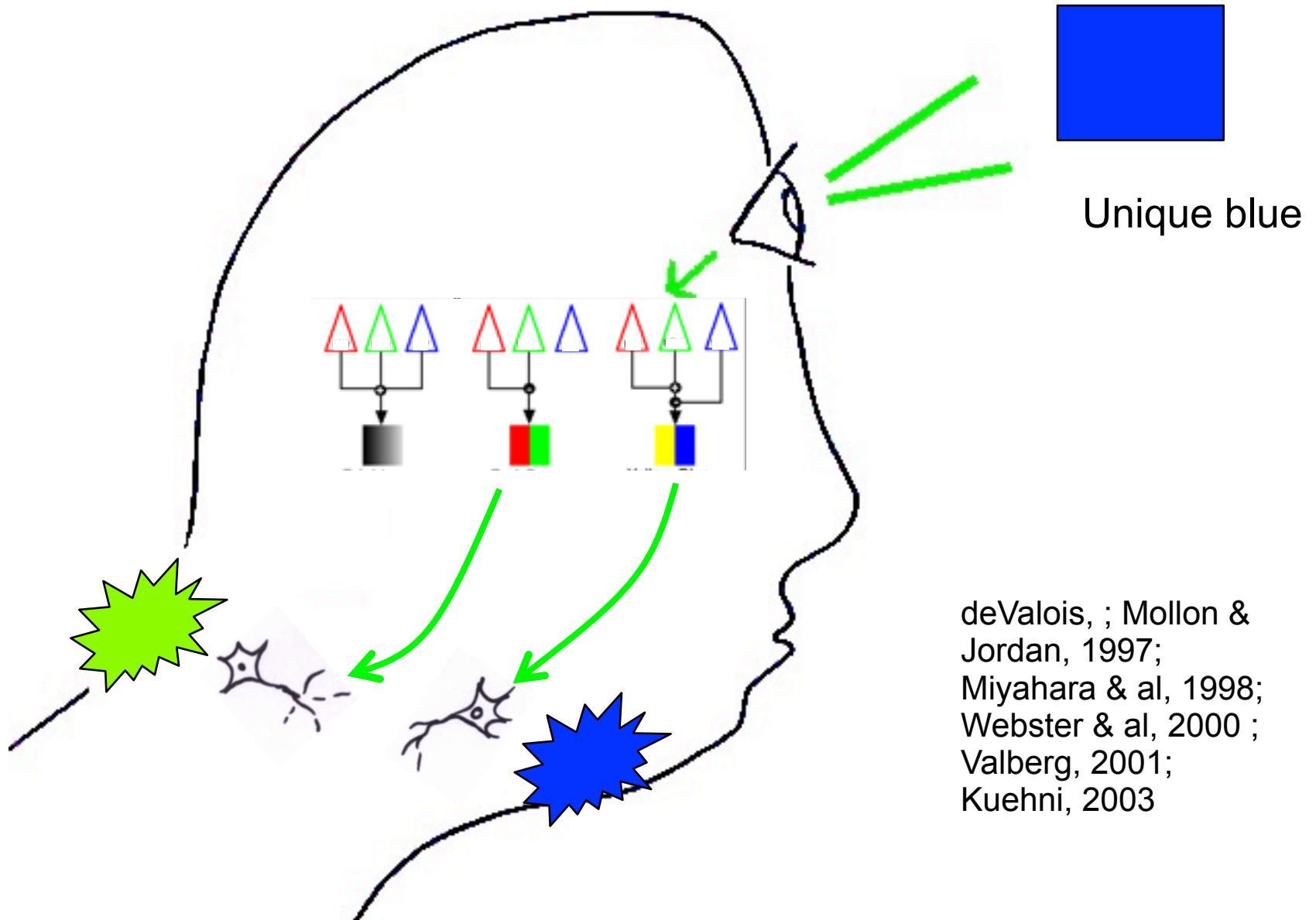


Luminance

Color

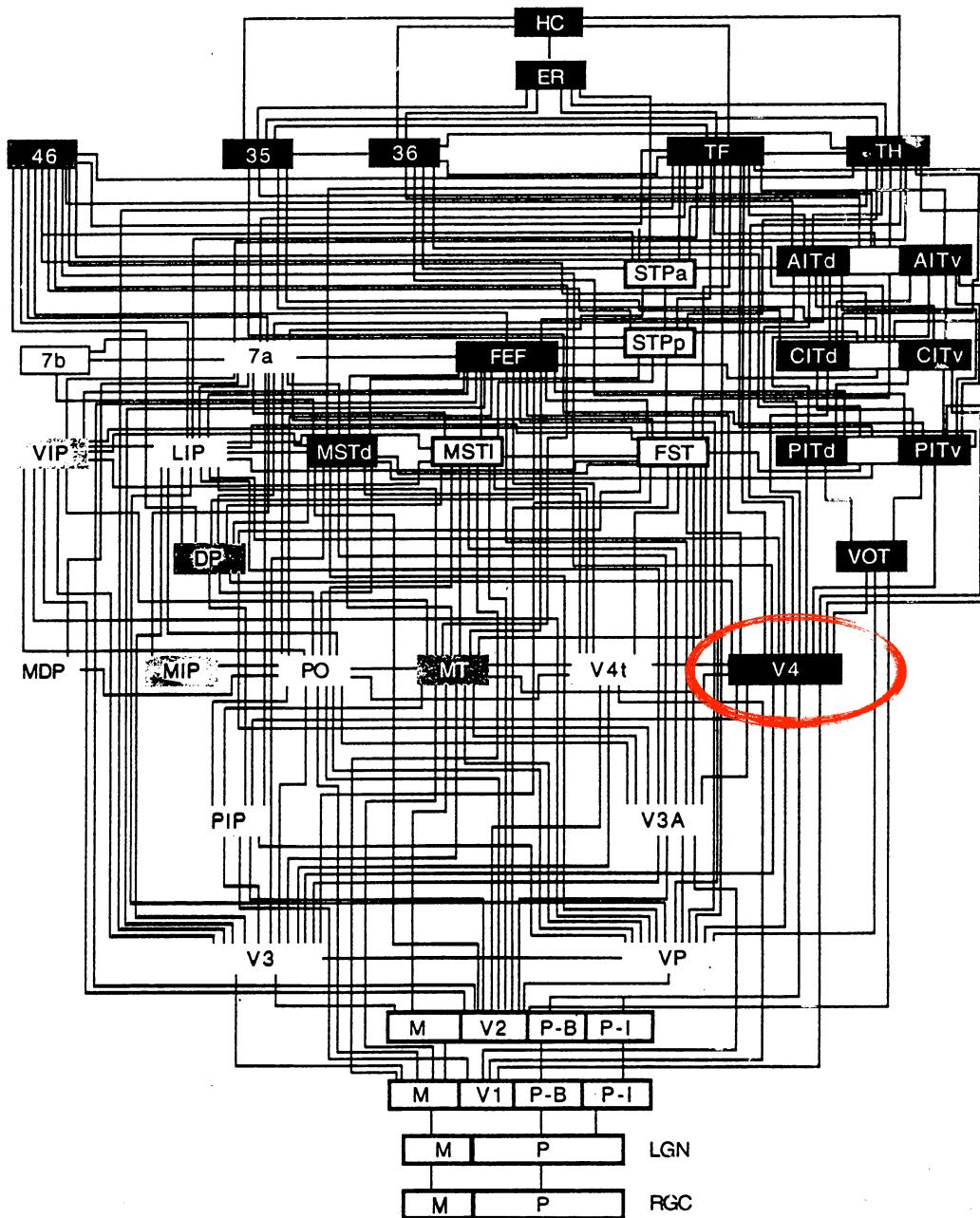






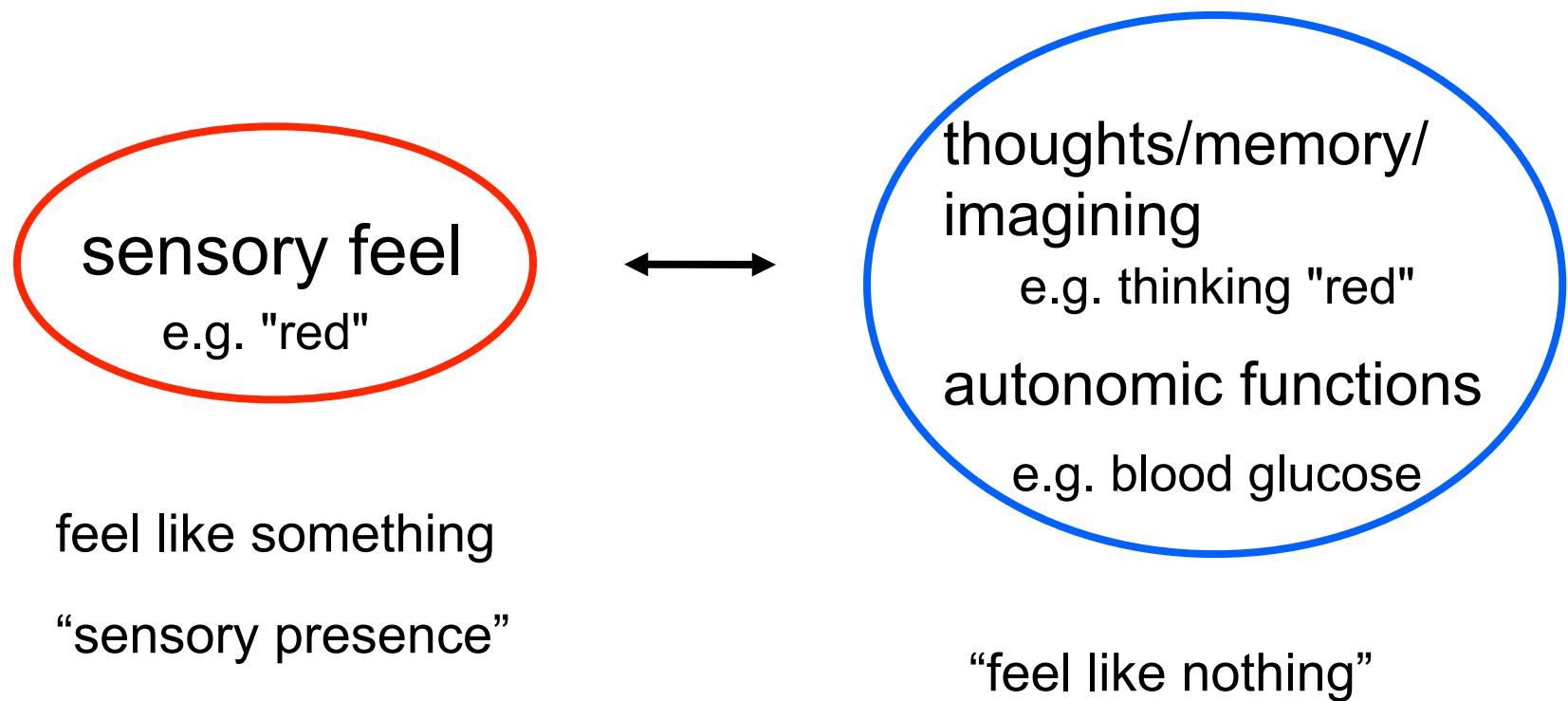
deValois, ; Mollon & Jordan, 1997;  
Miyahara & al, 1998;  
Webster & al, 2000 ;  
Valberg, 2001;  
Kuehni, 2003

# Connections between visual brain areas



Fellerman & van  
Essen (1991)

# Sensory "presence"



# The explanatory gap

## Making the link between physics and experience

- color//physiology
- sensory presence//physiology
  - no common language

# The explanatory gap

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## Analogy with vitalism

- “vital spirit” to explain life in biological entities

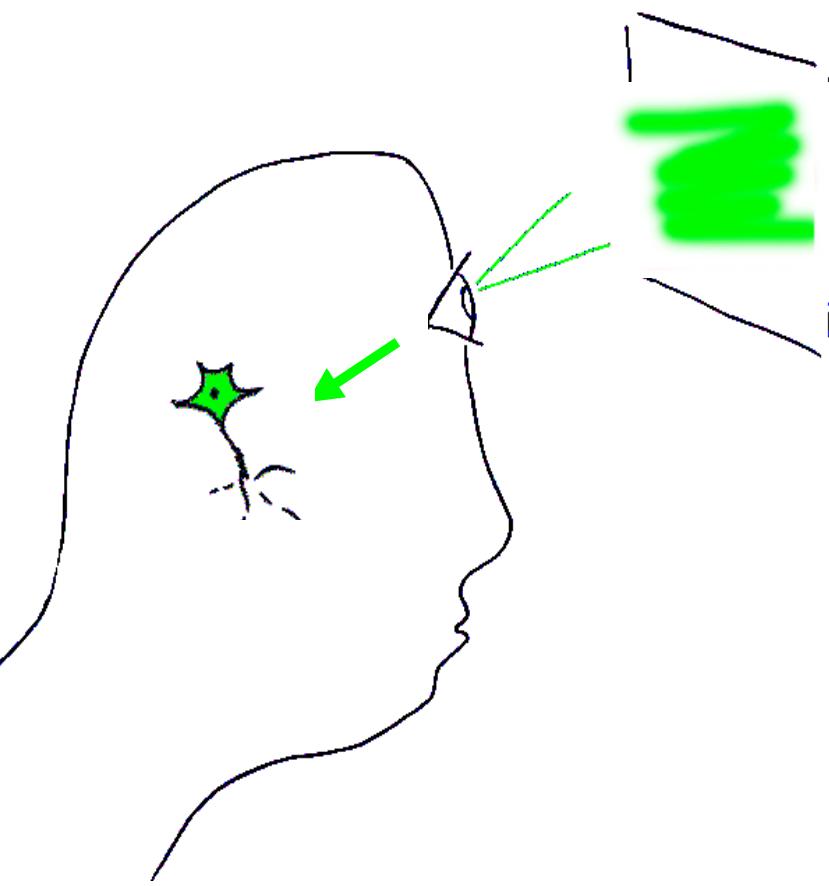
Today we know that life is *not the kind of thing that is generated*

It is a *word* that describes the way organic systems interact with environment

The quality of a feel is *the way we interact with the environment !*

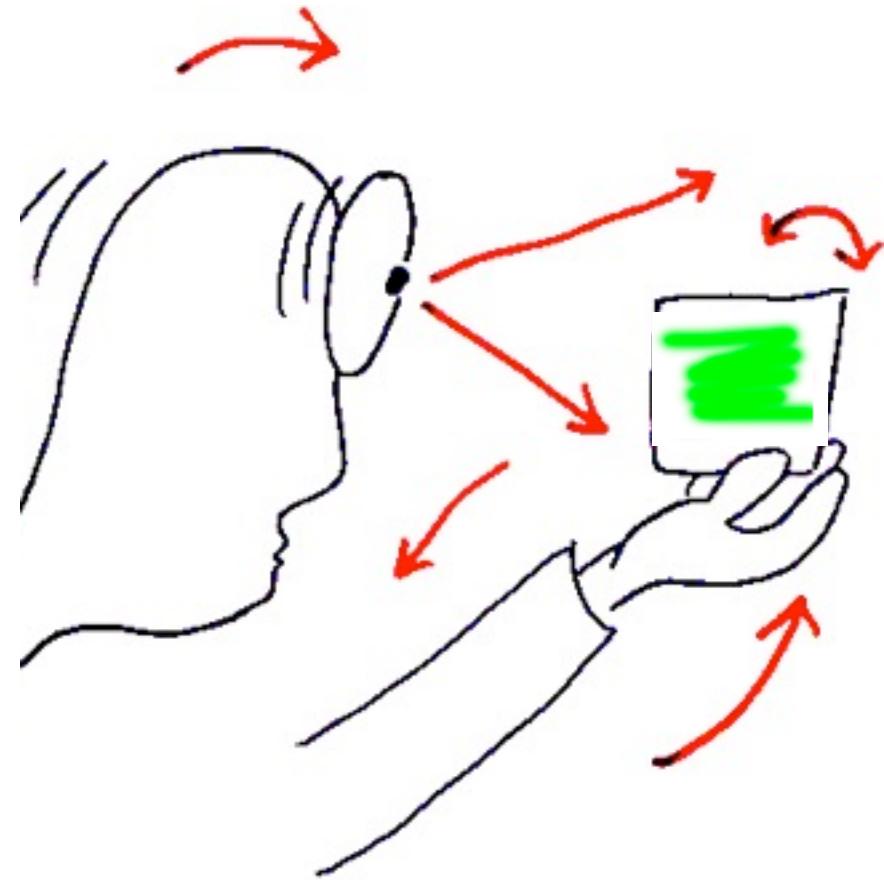
**standard view**

**Brain creates feel**

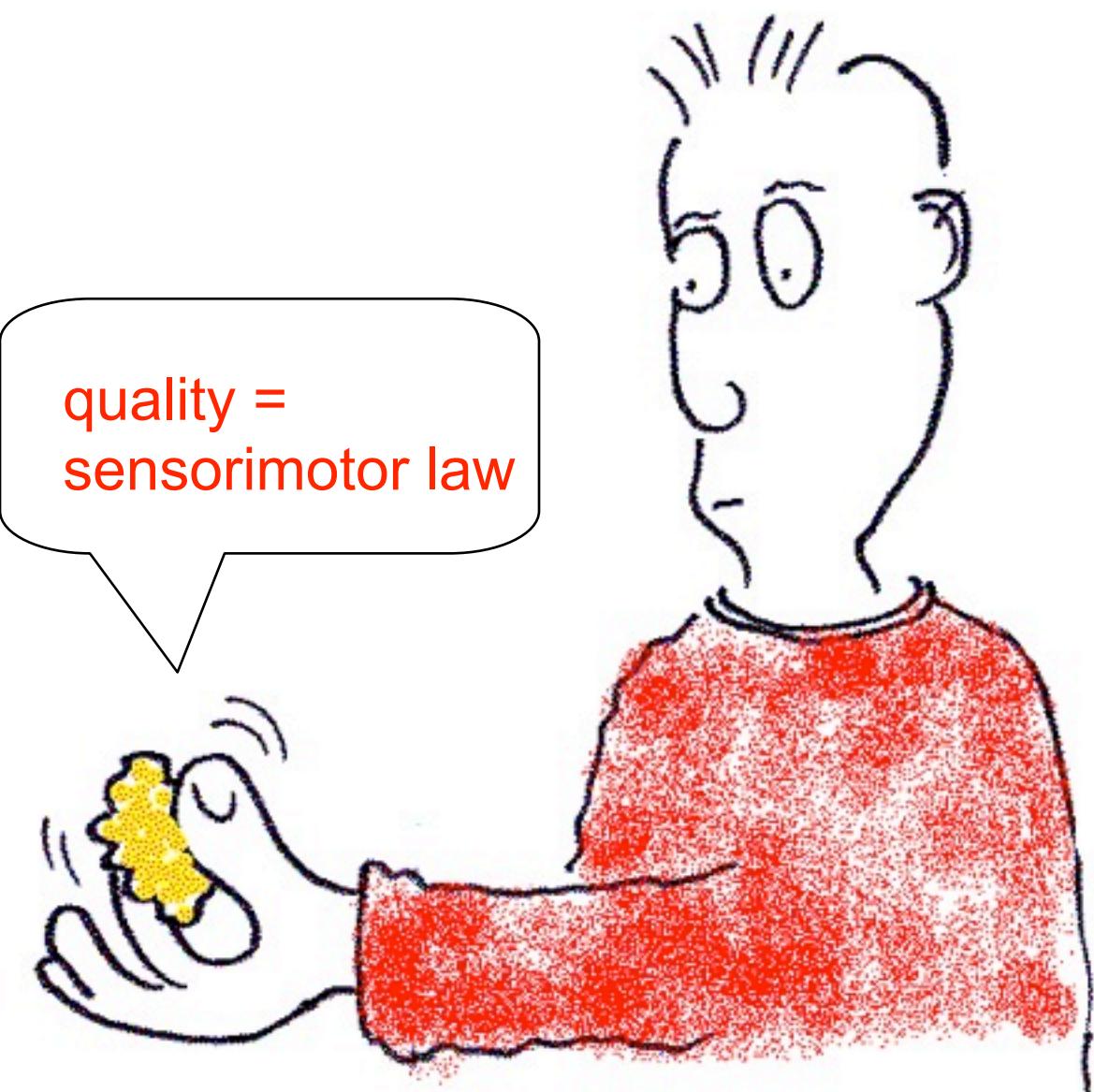


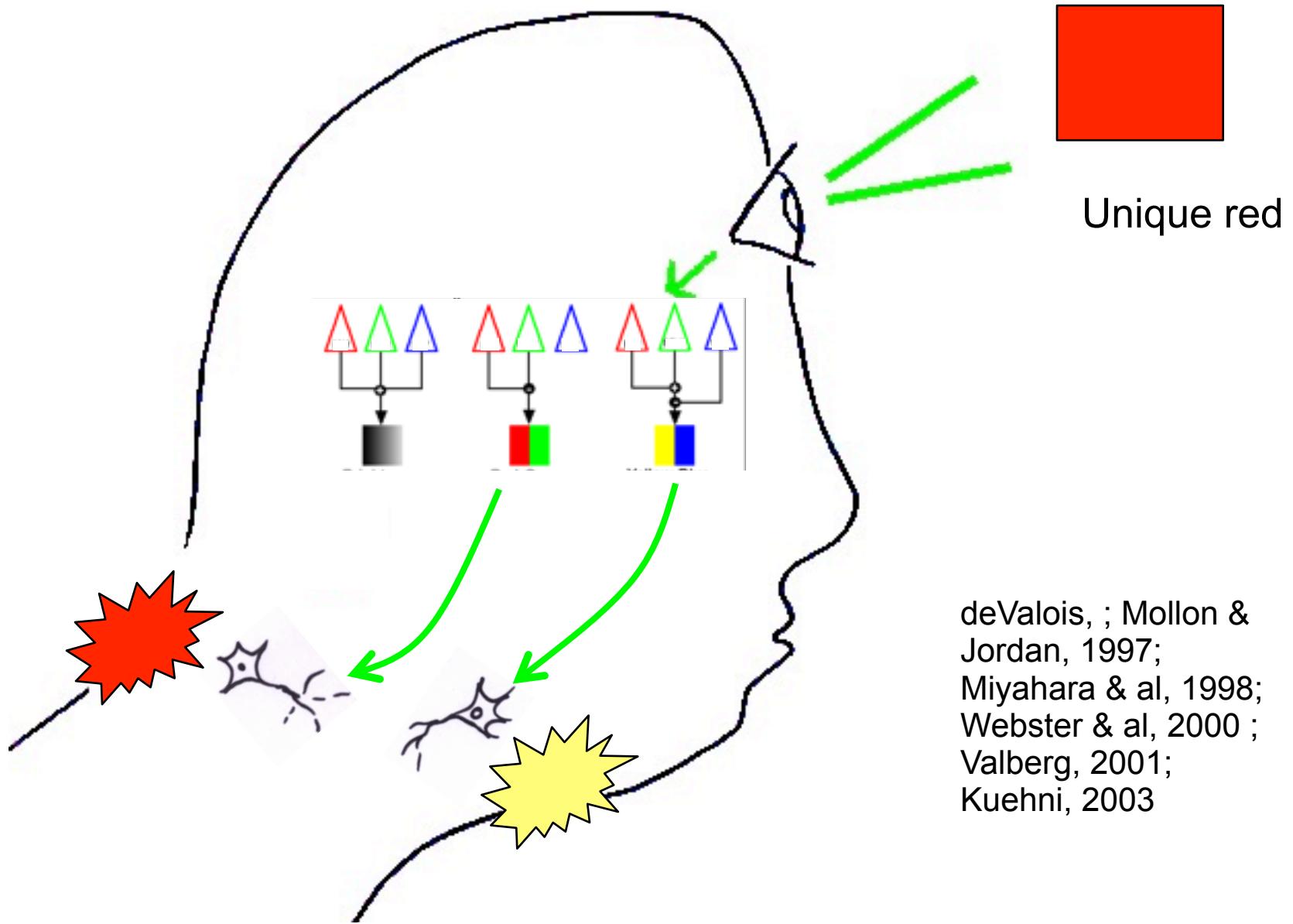
**sensorimotor view**

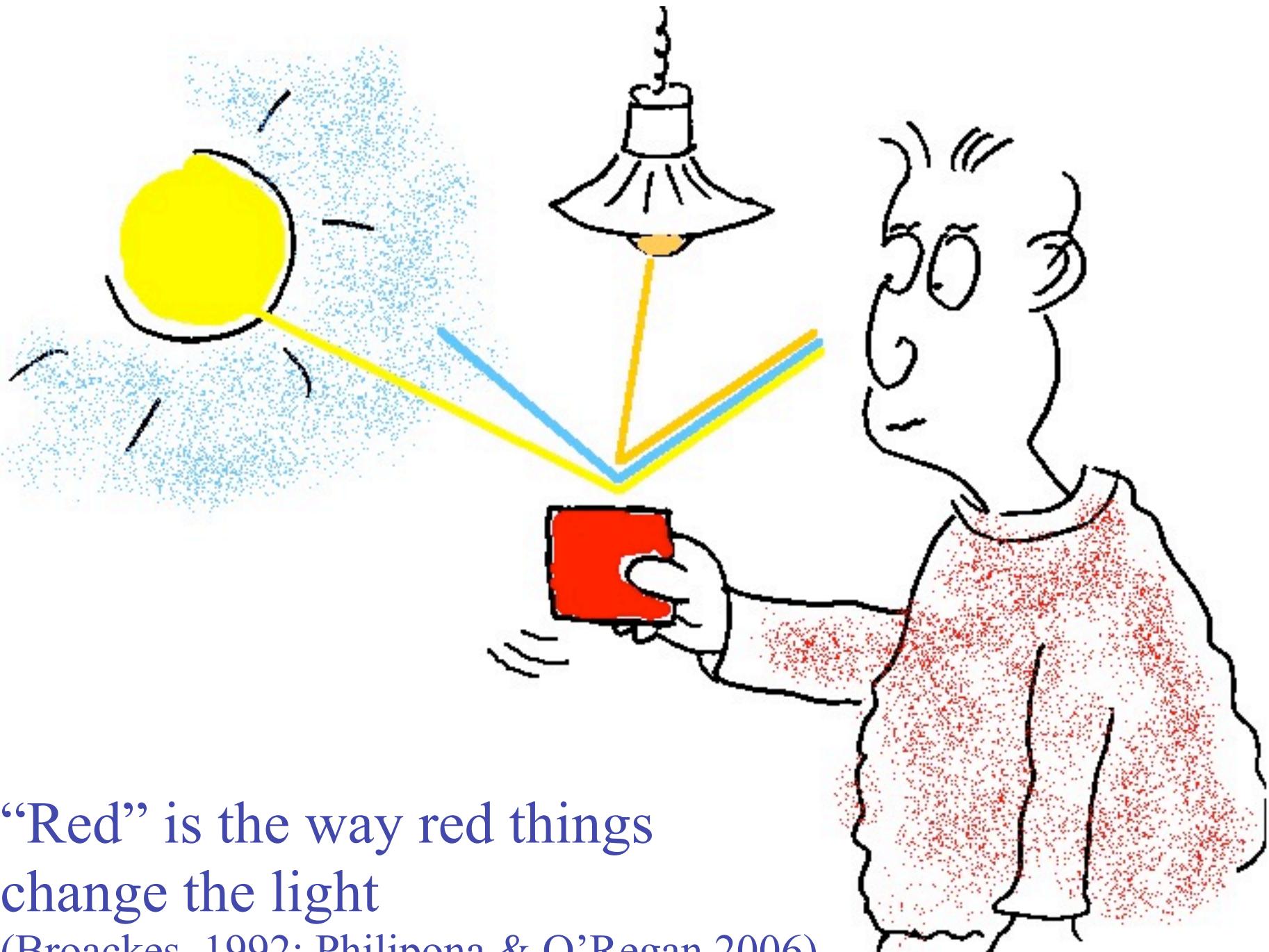
**Feel is a way of interacting**



# Sensorimotor view

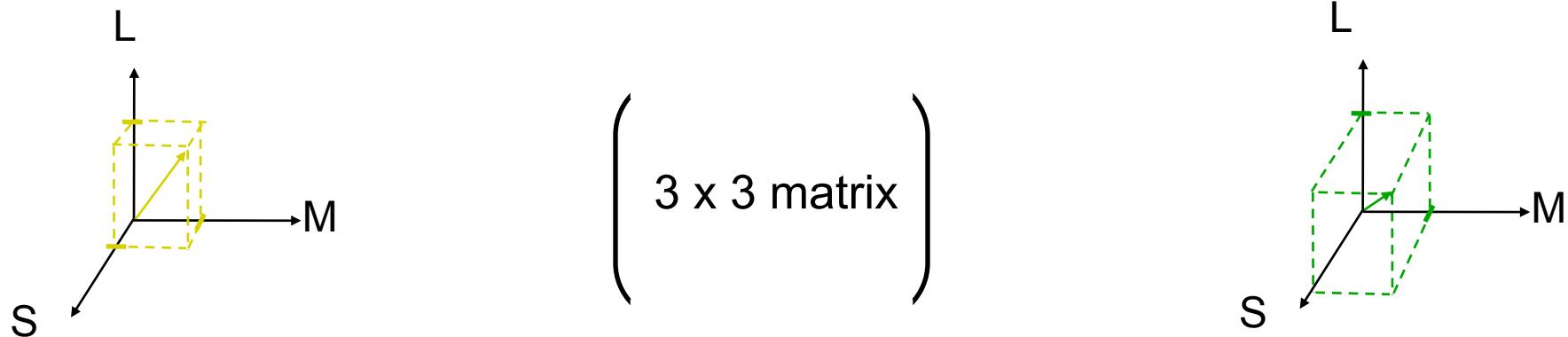
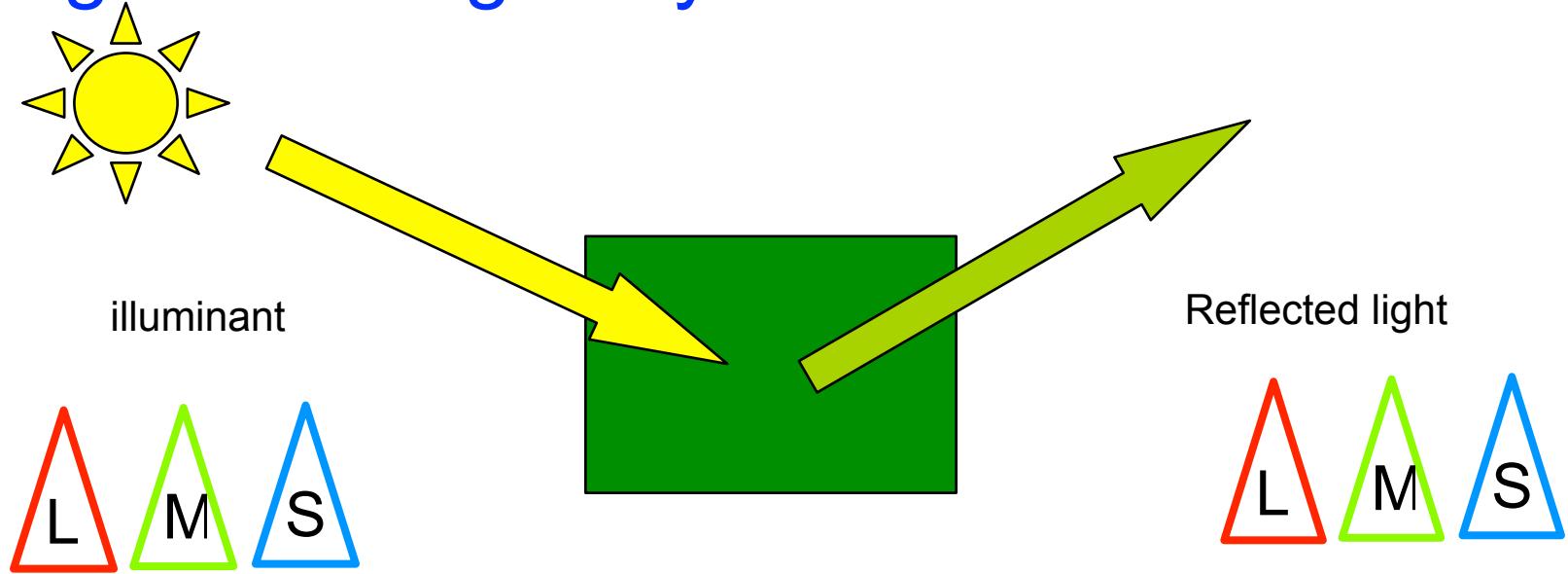






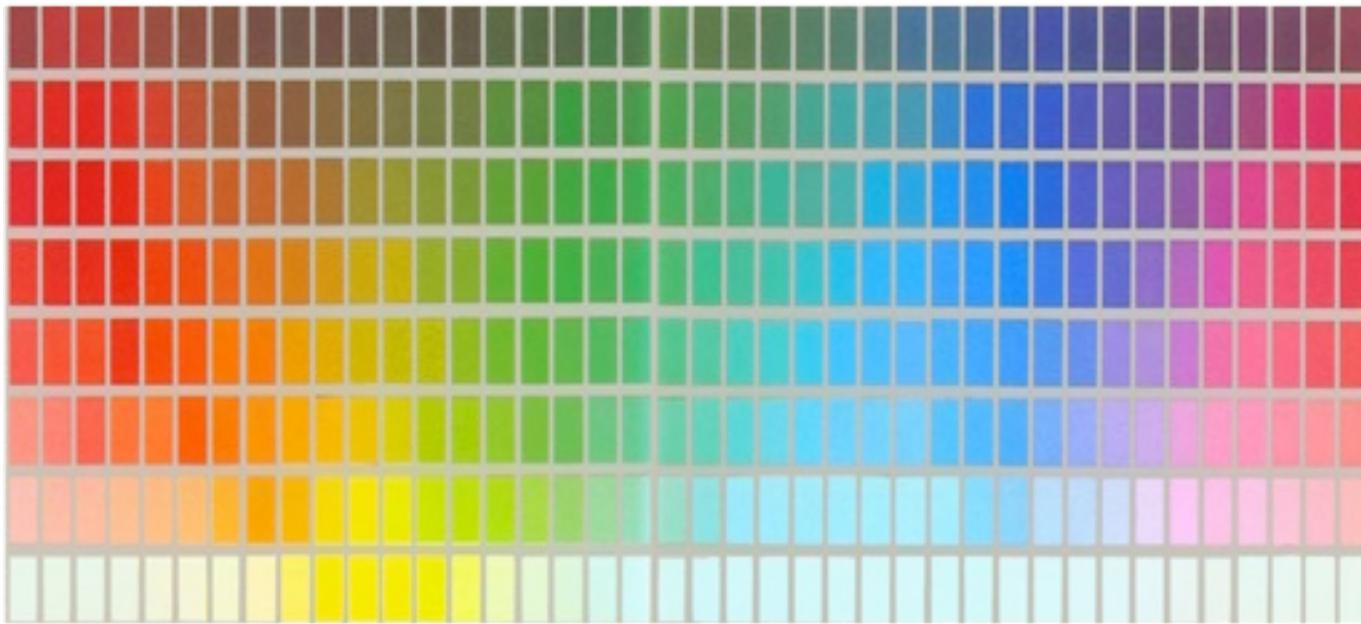
“Red” is the way red things  
change the light  
(Broackes, 1992; Philipona & O'Regan 2006)

# How light is changed by surfaces



# 1. Qualities have structure: Color

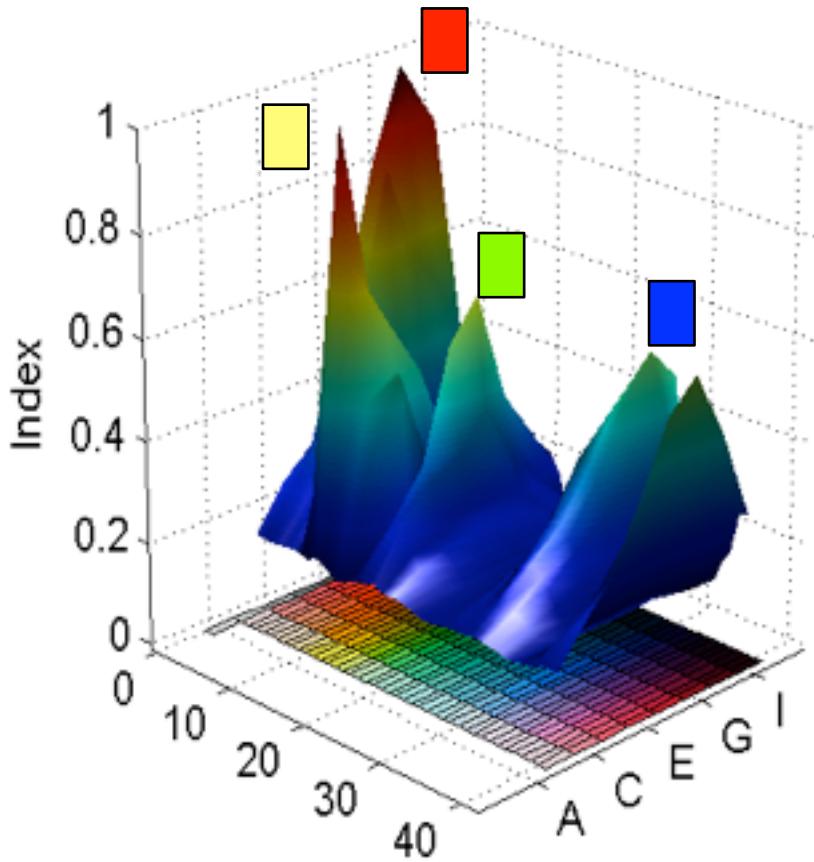
Munsell chips



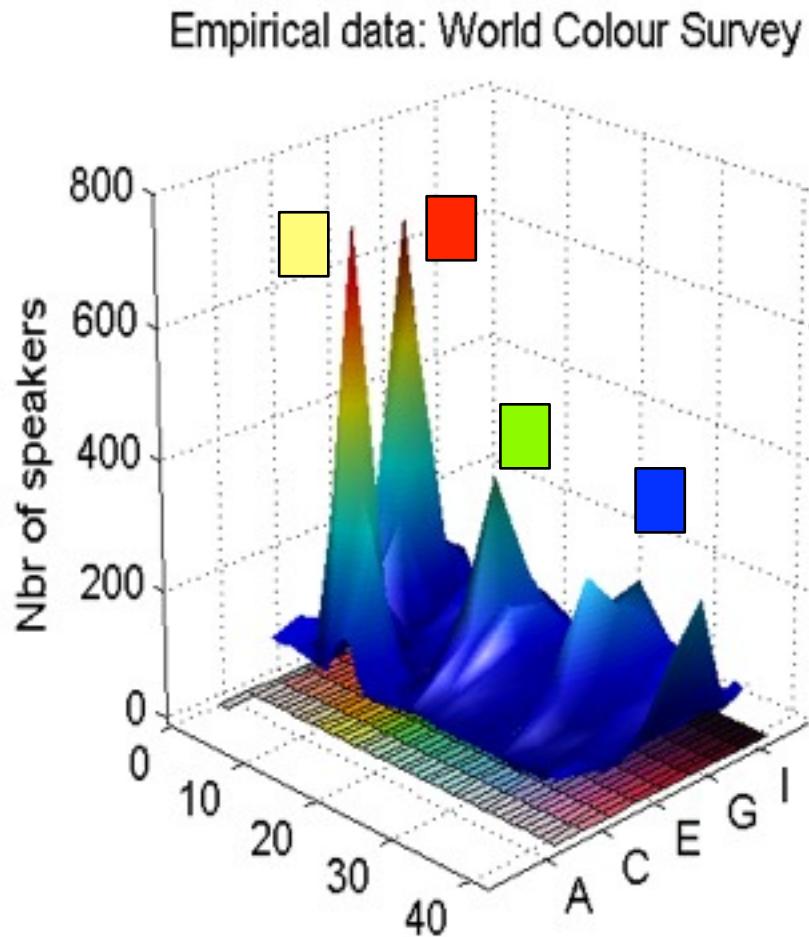
Philipona & O'Regan, Vis. Neurosci, 2006

# Singularity index

Computed singular reflecting properties

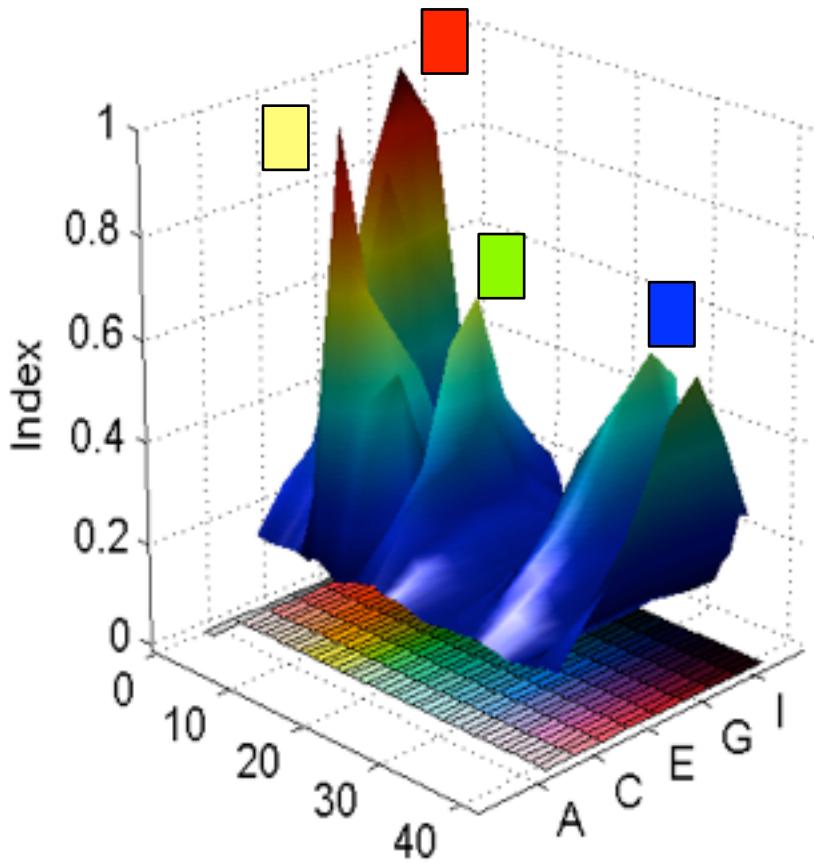


World Color Survey: "Focal colors"  
Berlin & Kay (1969); Kay & Regier (2003)



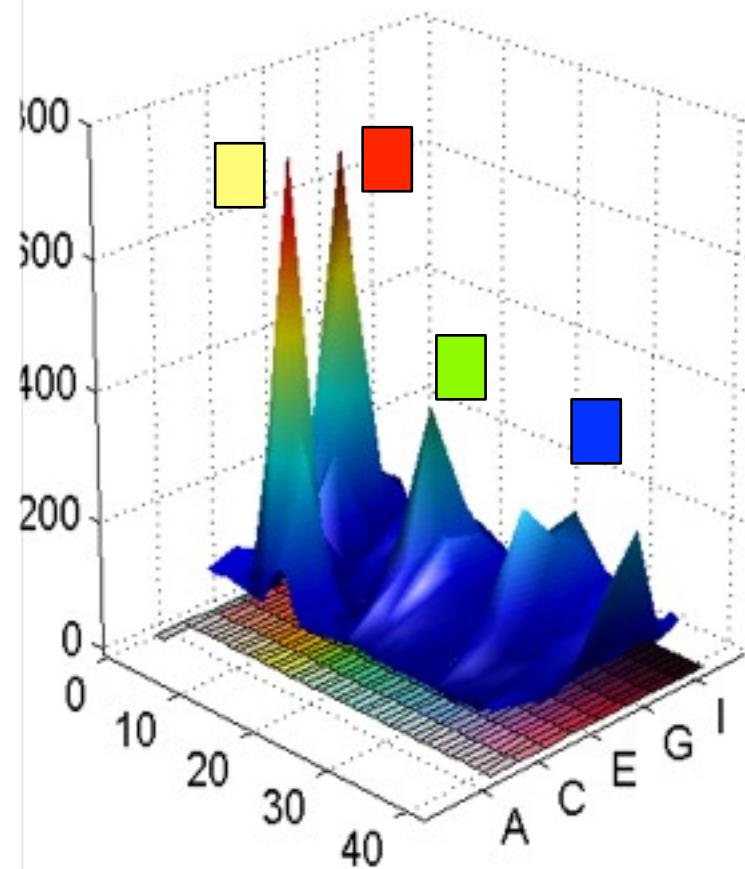
# Singularity index

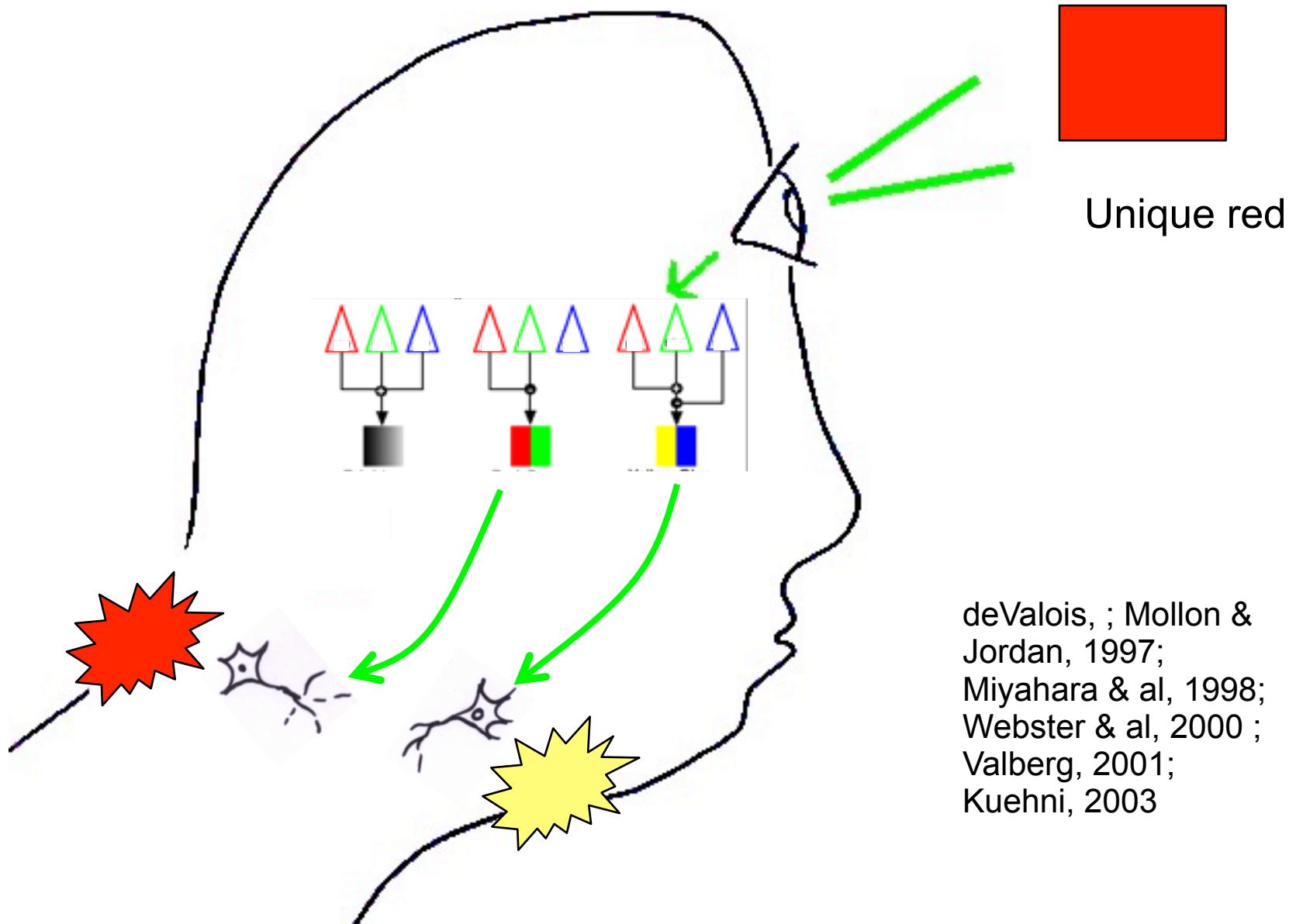
Computed singular reflecting properties

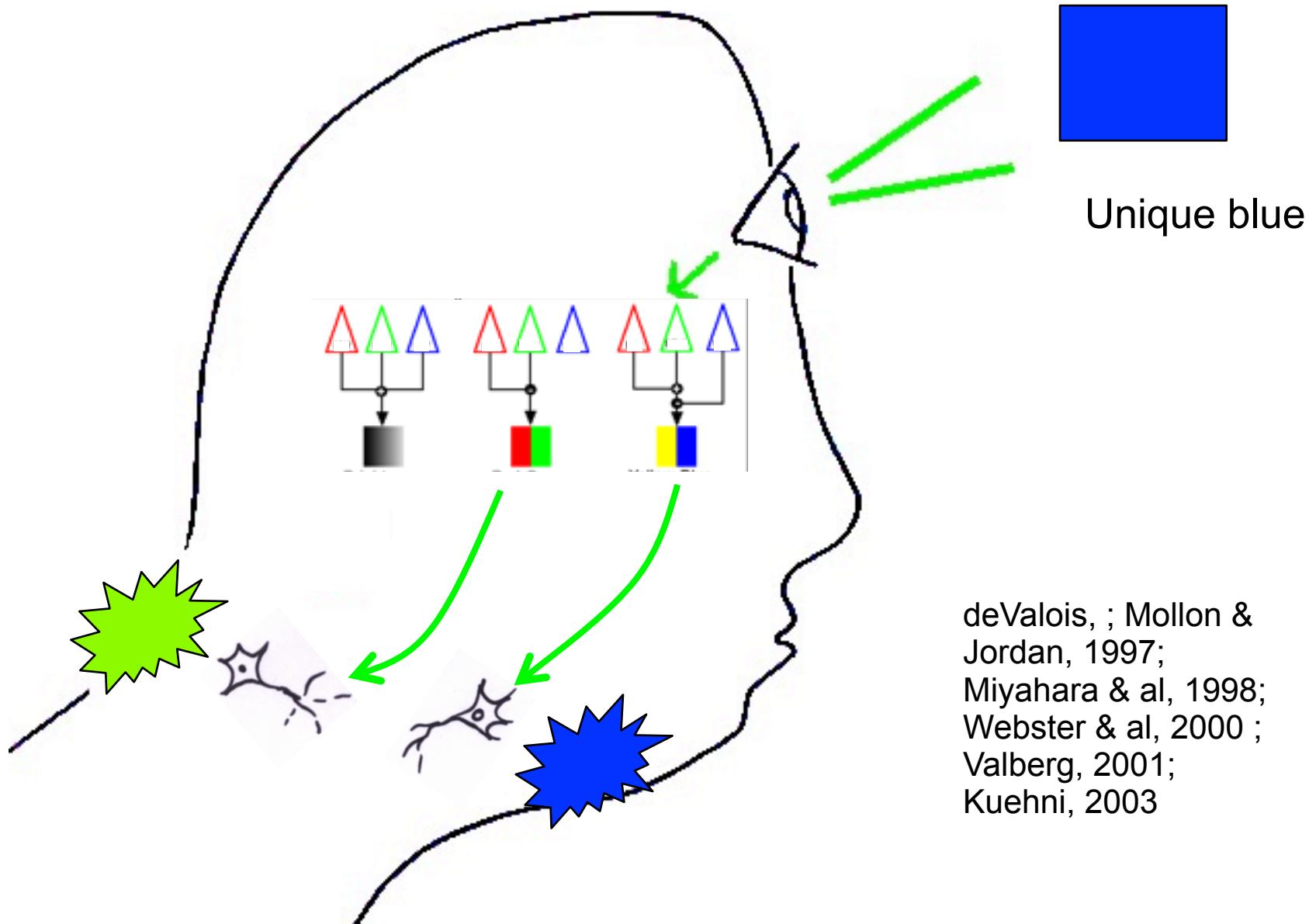


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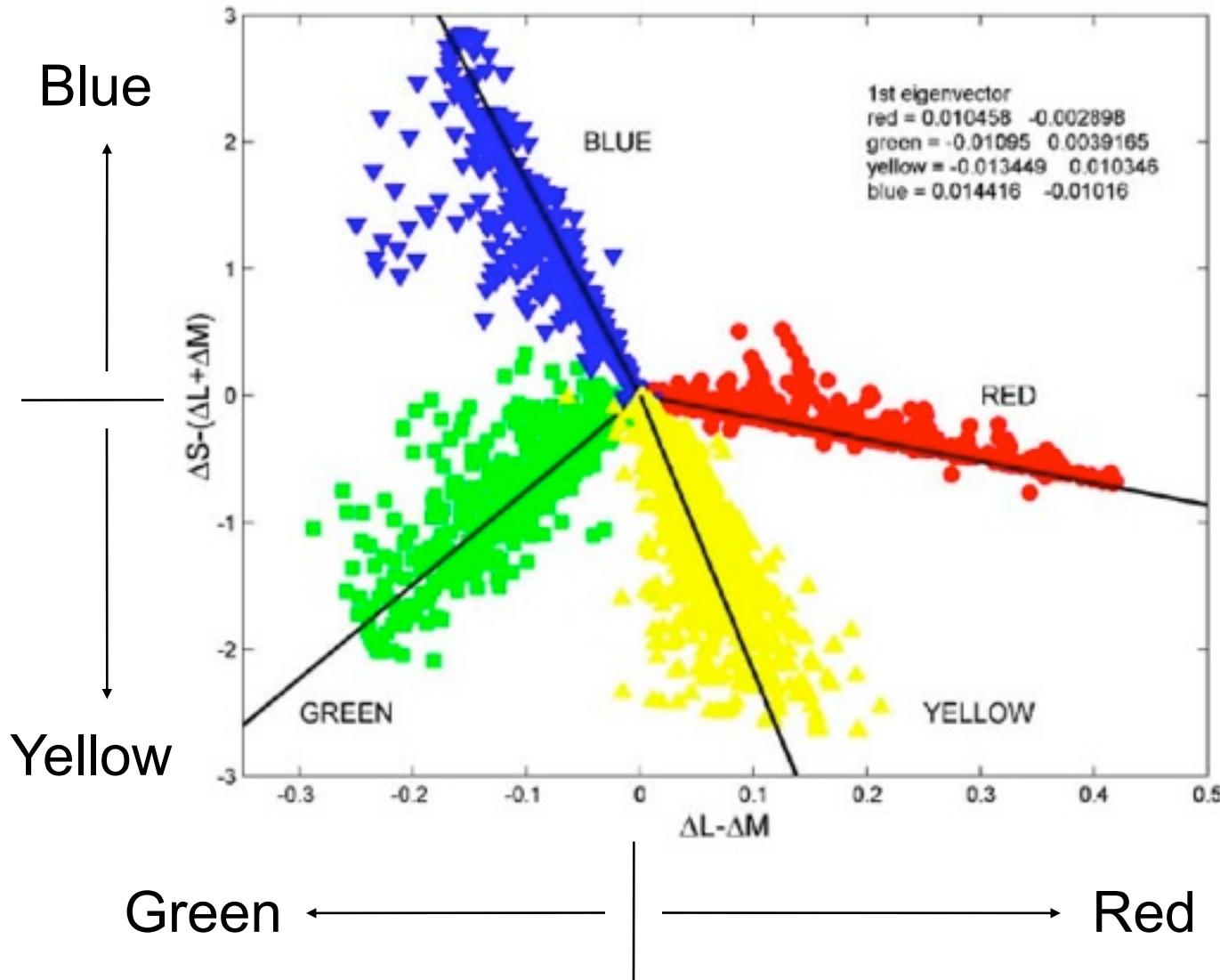
Empirical data: World Colour Survey







# Channel activations for unique hues



Wuerger 2005 (18 observers)

(also: deValois, Mollon & Jordan, 1997; Miyahara & al, 1998; Webster & al, 2000 ; Valberg, 2001; Kuehni, 2003)

# Predictions of sensorimotor approach

unique colors

sensory presence

sensory substitution

Rubber Hand Illusion

space

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unique colors

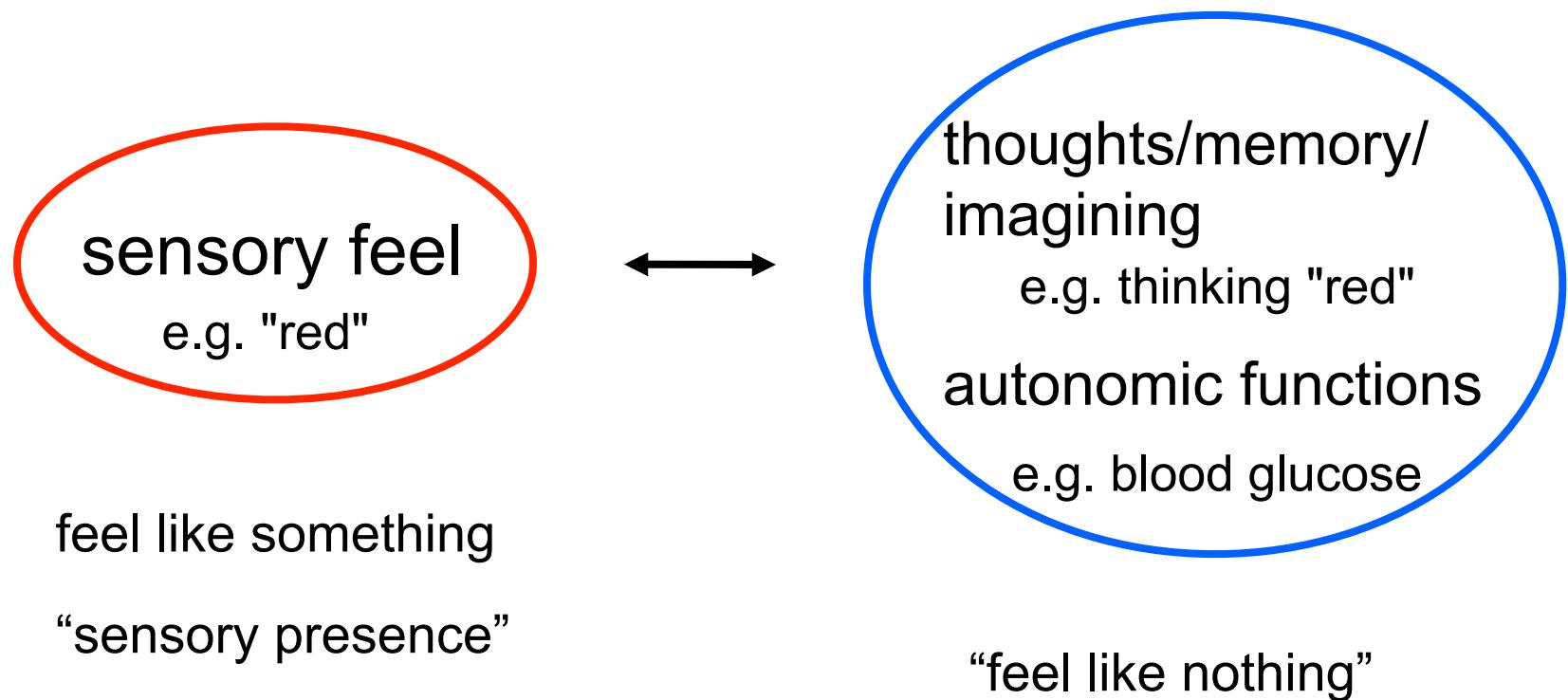
sensory presence

sensory substitution

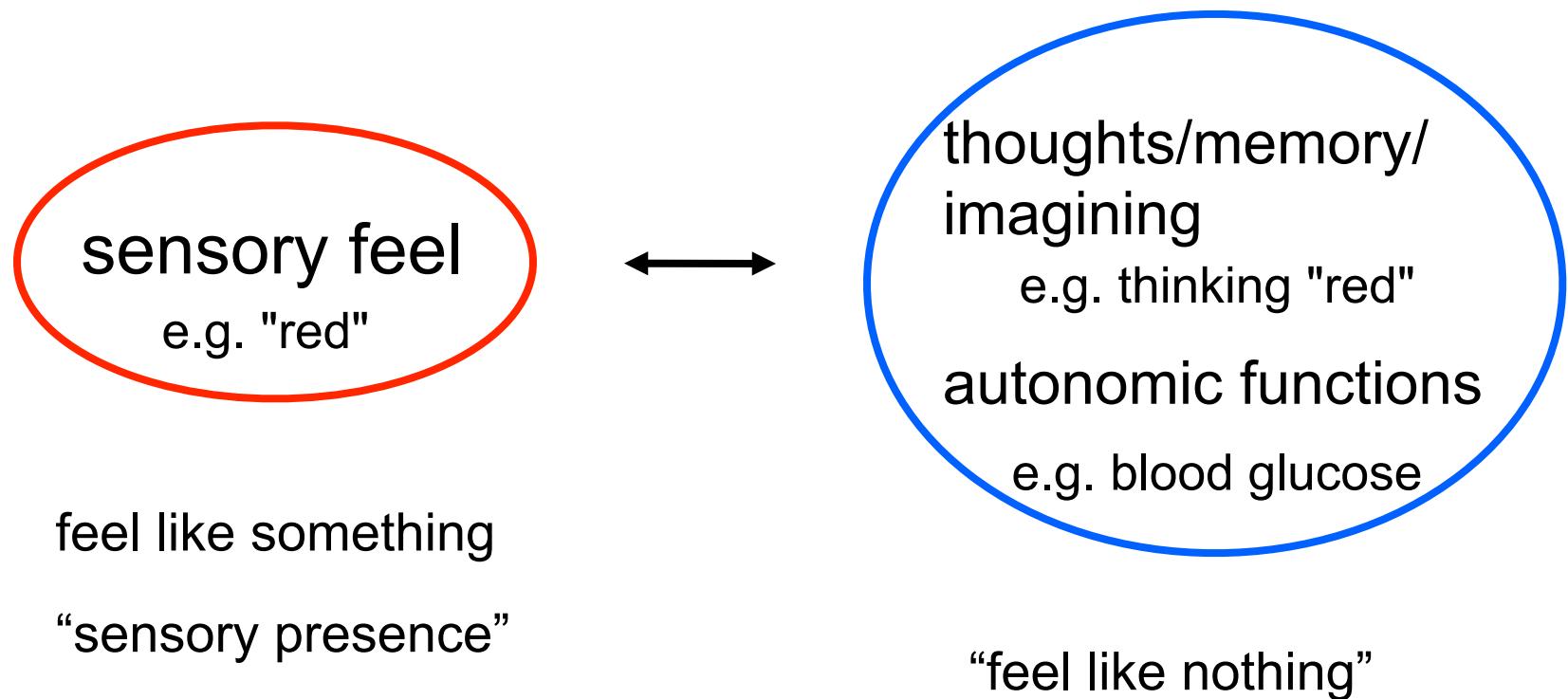
Rubber Hand Illusion

space

# Sensory "presence"



# Sensory "presence"



Explanation in terms of sensorimotor laws

# Sensory "presence"

## Sensorimotor interactions with the real world

### Bodiliness

- voluntary actions systematically change sensory input

### Insubordinateness

- sensory input can also change without voluntary actions

### Grabbiness

- sensory channels can incontrovertibly capture attention

# Sensation of seeing requires grabbiness

# Sensation of seeing requires grabbiness



**Change Blindness (using flicker)**  
(from J. Kevin O'Regan -- <http://nivea.psycho.univ-paris5.fr>)

Simons, Franconeri & Reimer, 2000; Auvray & O'Regan, 2003



Simons, Franconeri & Reimer, 2000; Auvray & O'Regan, 2003

# Change Blindness

Flicker

Rensink, O'Regan & Clark, 1997; 1999

Eye saccades

Currie, McConkie, Carlson-Radvansky & Irwin, 1995; McConkie & Currie, 1996

Blinks

O'Regan, Deubel, Clark, Rensink, 1999

Film cuts, real life

Levin & Simons, 1997

“Mudsplashes”

O'Regan, Rensink & Clark (Nature, 1999)

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# Sensory input coming into the brain

t=0

neural input: 13, 21, 242, 16, 22, 11, 21, 99, 56, 11, 11, 12, 134, 67 ...

t=1

neural input: 13, 98, 74, 3, 24, 36, 45, 79, 17, 34, 24, 35, 73, 112, 23 ...

t=3

- ACTION -

neural input: 14, 22, 132, 8, 12, 78, 54, 13, 98, 74, 3, 24, 36, 45, 79, 17, 34 ...

...

**Space is hidden in these activations! How can it be deduced without knowing a priori that it is there?**

where is the body? where is the environment?

# Method

Study sensorimotor dependencies:

Make random actions

Assume sometimes environment moves

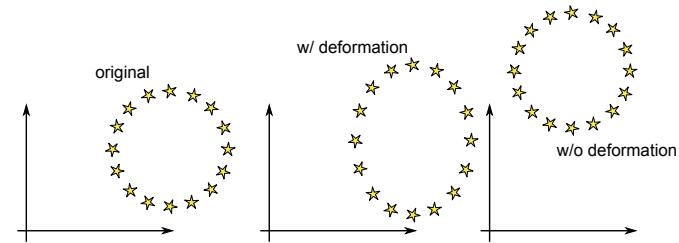
sometimes rigid motions

sometimes non-rigid

Register cases where sensory input is THE SAME (coincidence detection)

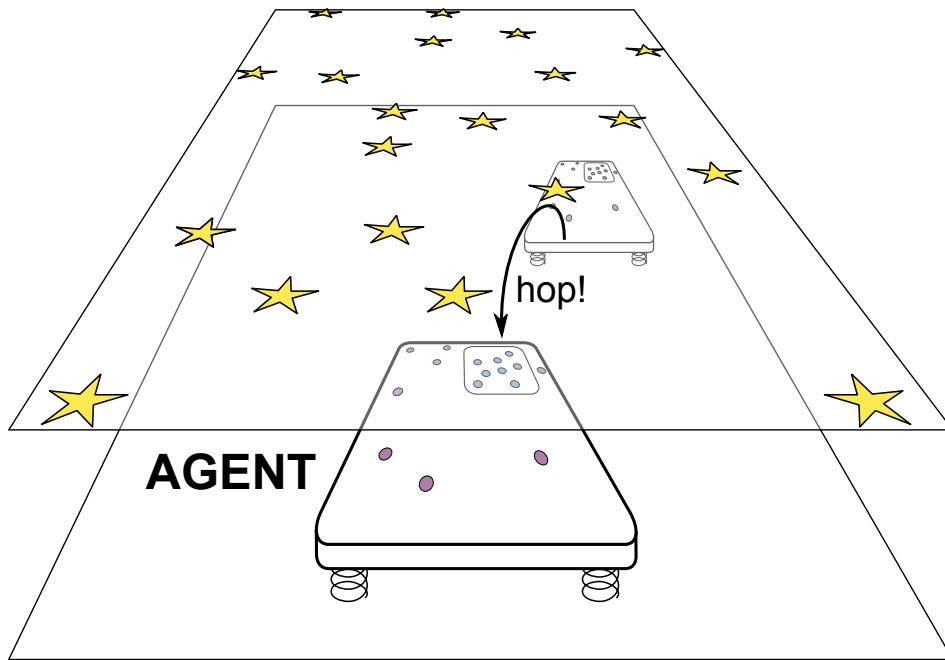
Make map between corresponding proprioceptive values: functions  $\Phi$

These correspond to RIGID DISPLACEMENTS of the agent/environment



# Flatland agent

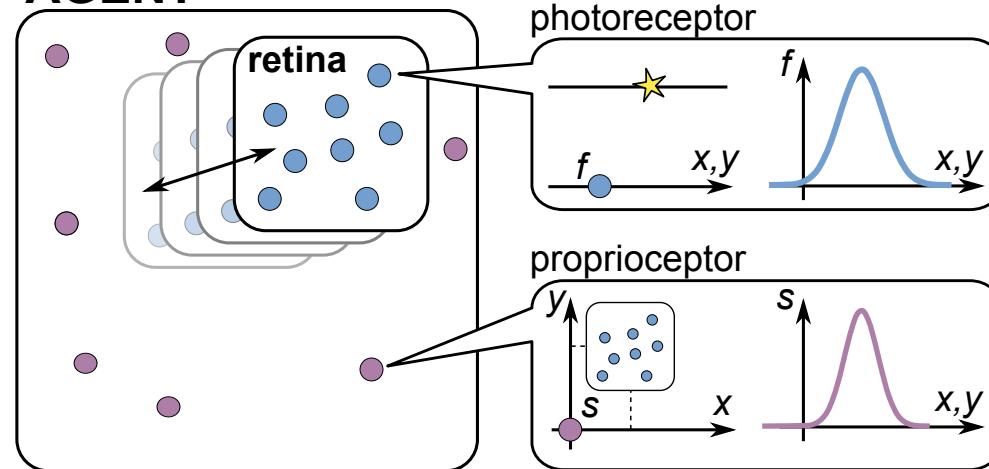
## ENVIRONMENT



2D body in 2D environment of light sources

makes hops

## AGENT



9 photosensors (sensitive to relative distance)

can move up/down, back/forth within body

8 proprioceptors

# Tests of spatial knowledge

## ≈ Turing test

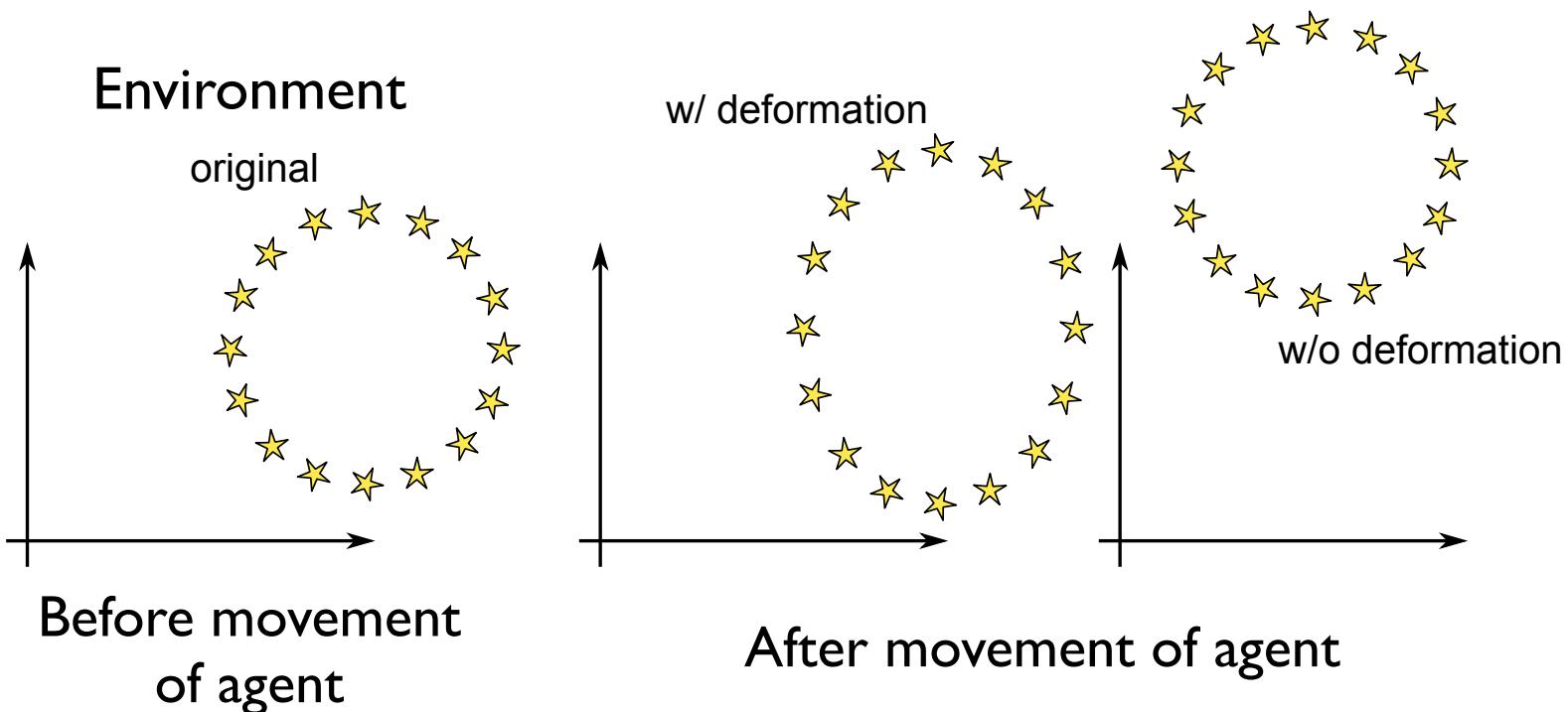
**agent is like the subject in a psychophysical experiment**

**ask the agent questions requiring spatial knowledge**

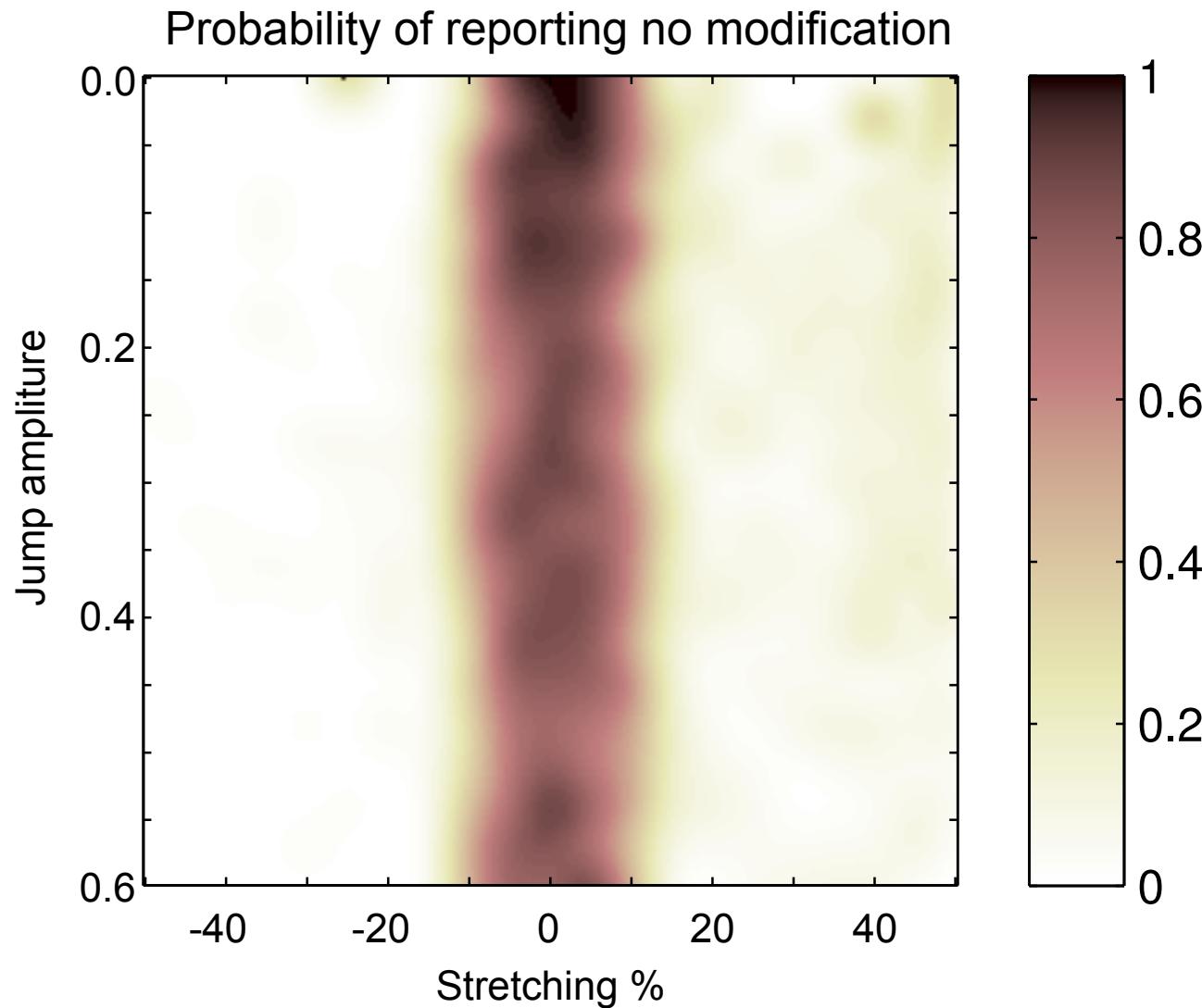
**space as a vessel**

- Test 1: discriminating self motion from environmental changes
- Test 2: notion of "path"
- Test 3: notion of displacement

# Test I - discriminating self motion from environment changes



# Test I - discriminating self motion from environment changes



The agent can distinguish changes caused by pure displacements from changes including distortions

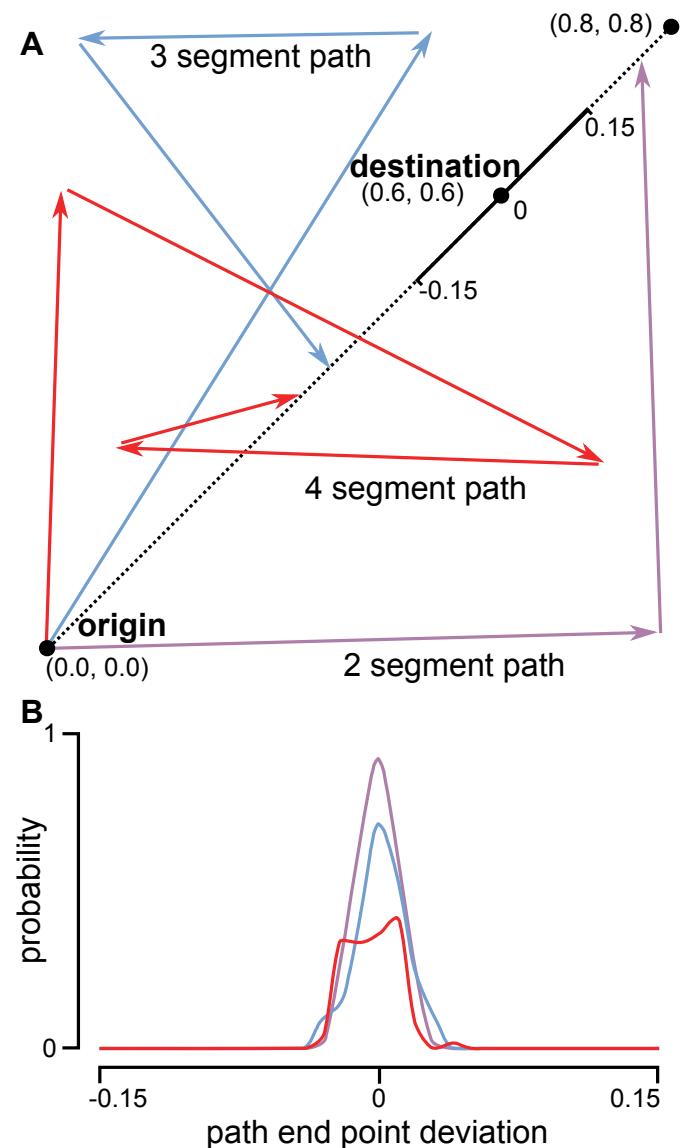
## Test 2: Notion of "path"

Starting from origin, go to various points near destination

Change the environment randomly on each trip (notion of **path**)

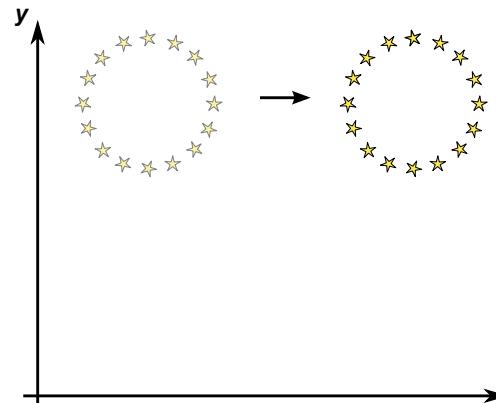
2, 3 and 4-segment paths

Probability that agent will judge the location to be the same.

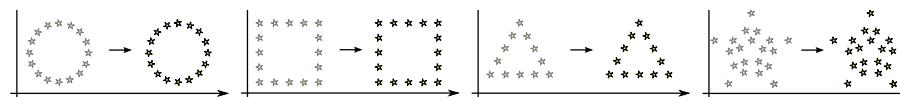


# Test 3: Notion of "displacement"

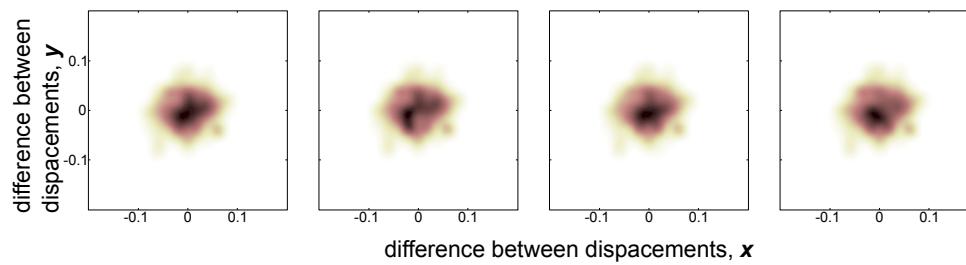
REFERENCE DISPLACEMENT



TEST DISPLACEMENT



PROBABILITY OF IDENTIFYING TEST AND REFERENCE



# **Conclusion on space**

**Naïve agent can extract the notion of space as a vessel**

**studying sensorimotor contingencies, and functions  $\varphi$**

**rigid motions**

displacement, path, relative position,

**independent of agent/environment properties, sensory/motor codes**

**intimate link of spatial notions with possible actions**

**Spatial dimensions correspond to dimensions of possible compensatory actions**

**Without ability to act, no notion of space**

# Predictions of sensorimotor approach

unique colors

sensory presence

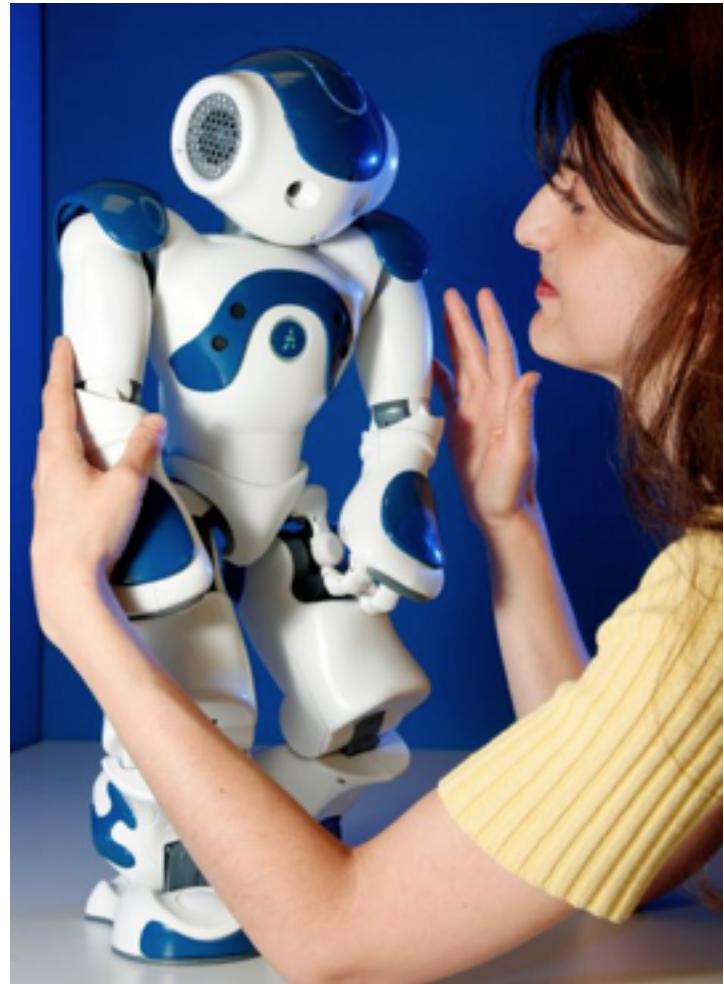
sensory substitution

Rubber Hand Illusion

space

# Will robots REALLY have emotions one day?

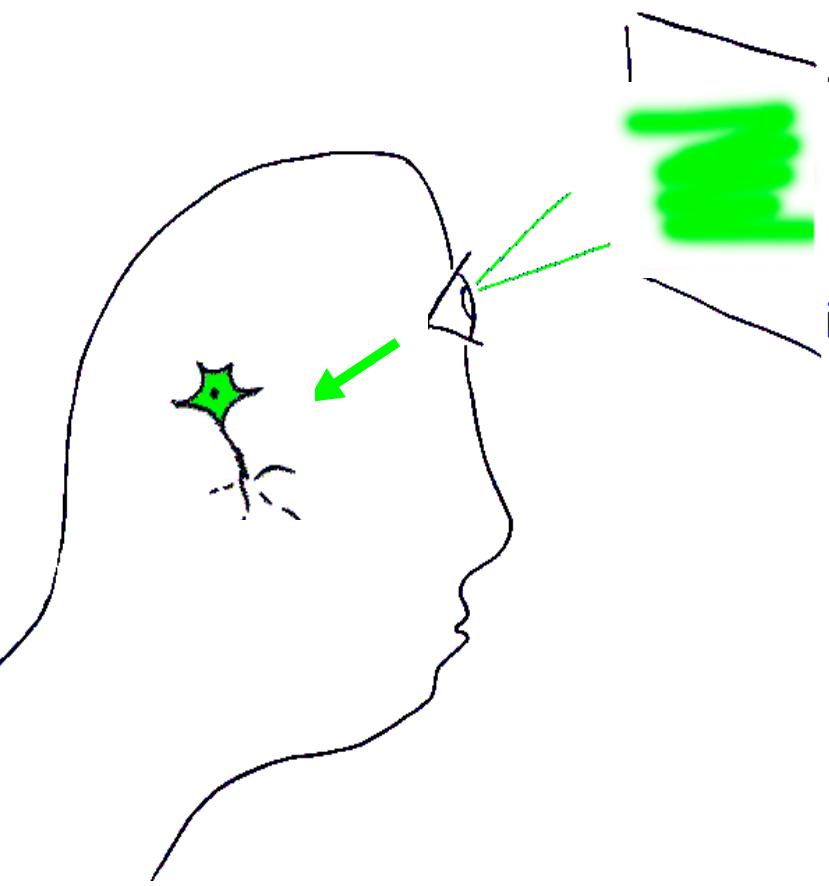
✓ Feel



*University of Hertfordshire researcher Dr Lola Canamero with Nao, a robot that can show its emotions and form a bond with humans*

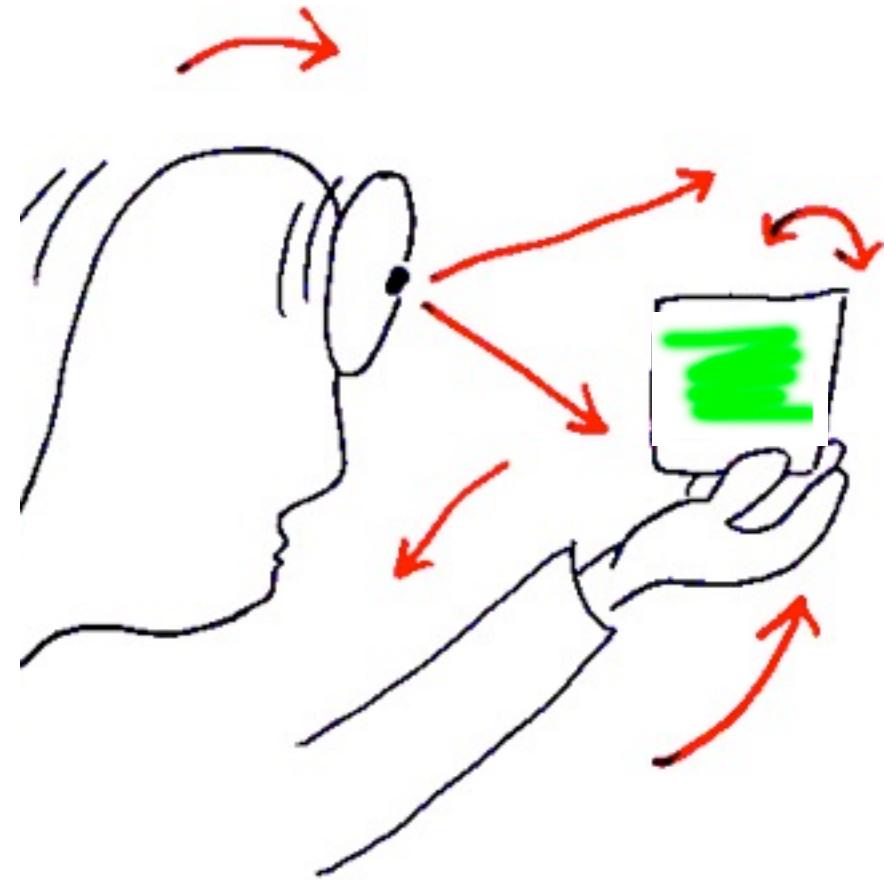
**standard view**

**Brain creates feel**

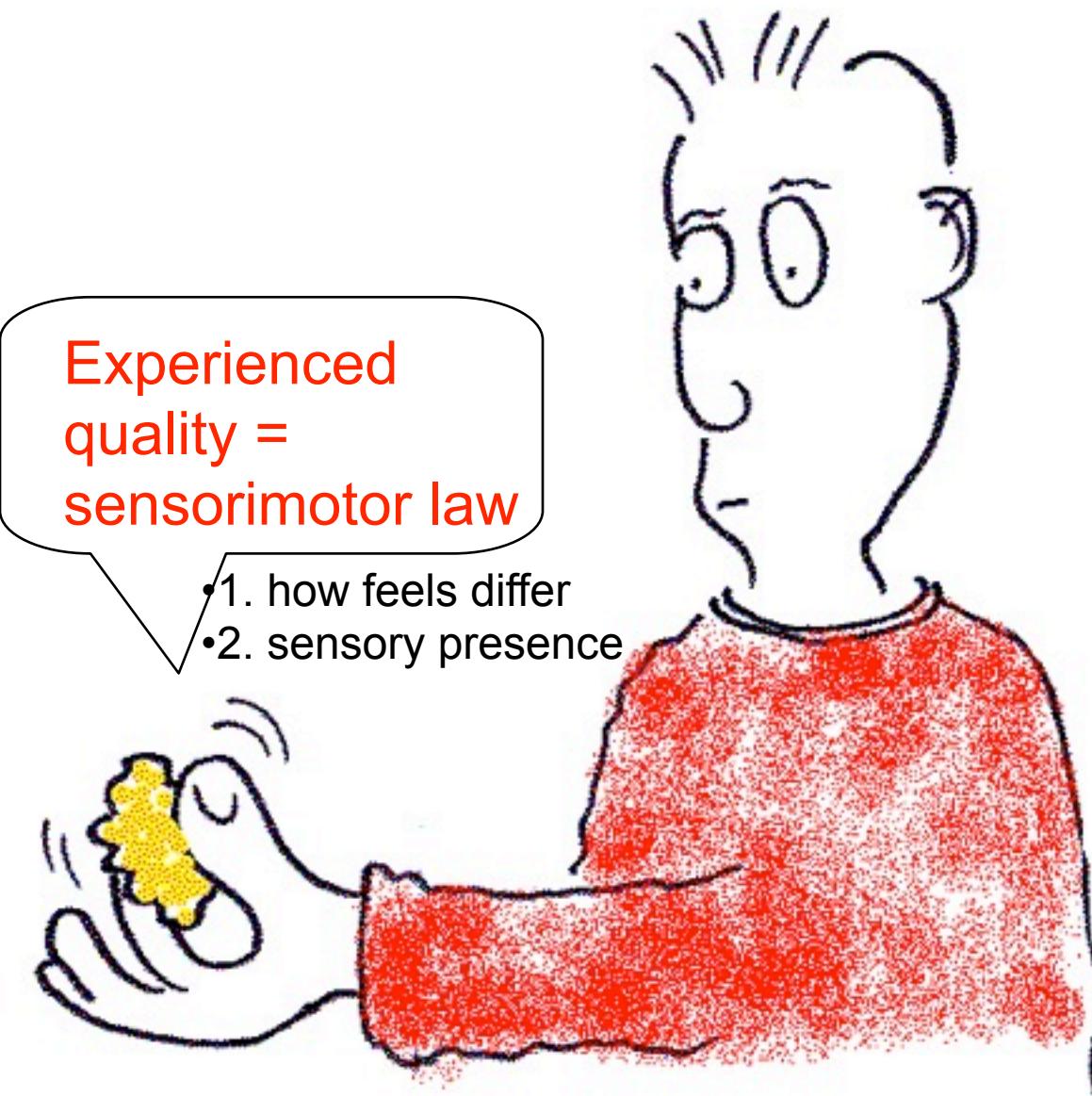


**sensorimotor view**

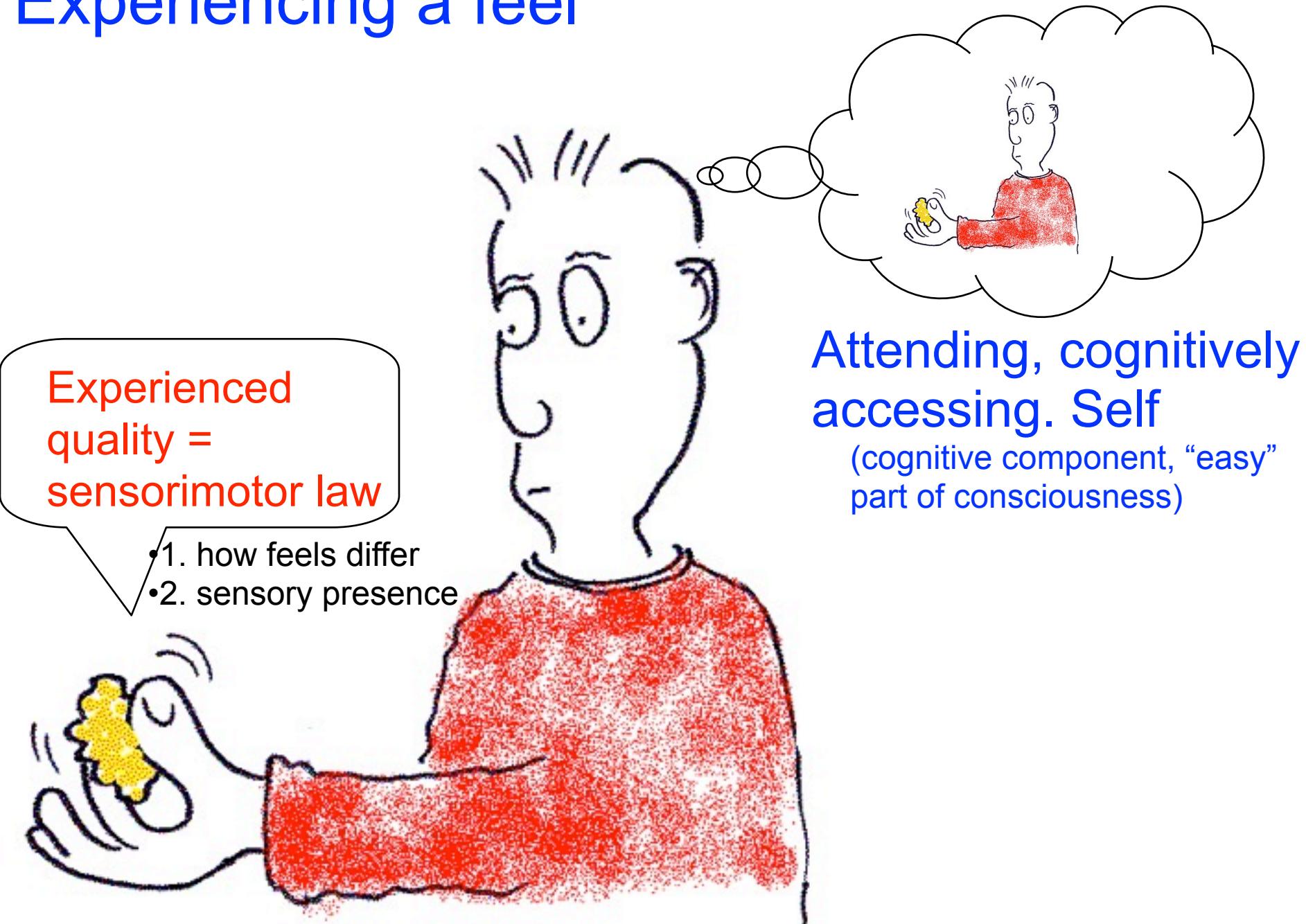
**Feel is a way of interacting**



# Experiencing a feel



# Experiencing a feel



# Will robots REALLY have emotions one day?

- ✓ Feel
- ✓ Cognitive access, self
- ✓ Emotions

yes! in the next 20 years!



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J. KEVIN O'REGAN

O'Regan, J.K. "Why red doesn't sound like a bell:  
understanding the feel of consciousness."  
Oxford University Press, 2011



Work partially financed by



European Research Council