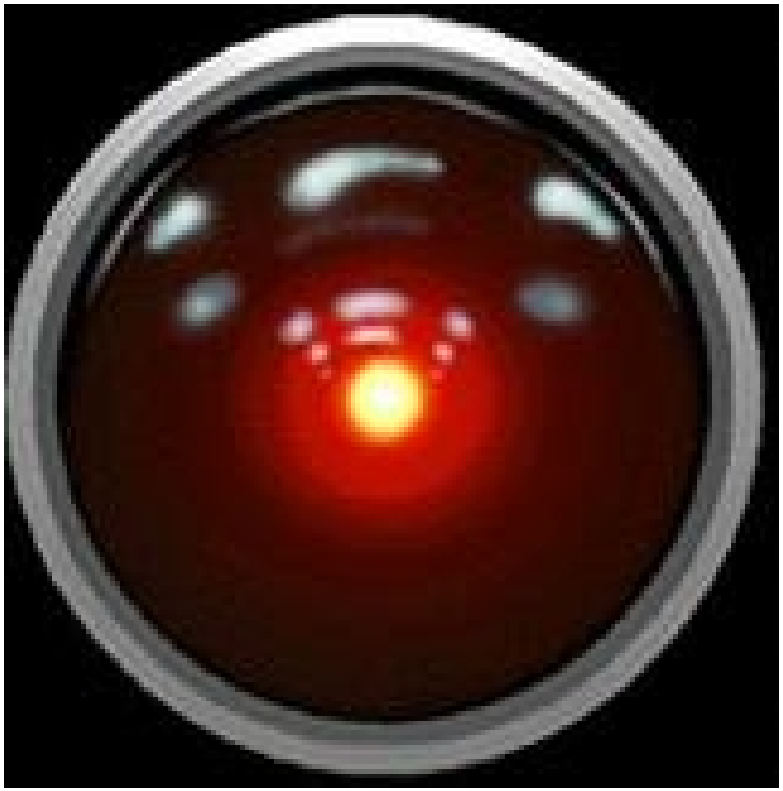


CS 378: Autonomous Intelligent Robotics

Instructor: Jivko Sinapov

http://www.cs.utexas.edu/~jsinapov/teaching/cs378/

Theories of Vision

Announcements

Homework 6 is out, due 4/5

Start early!

Announcements

Volunteers needed for another study!

As before, there will be extra credit

To sign up, email:

- Rodolfo Rodriguez <rcorona@utexas.edu>
- Jesse Thomason <thomason.jesse@gmail.com>

Final Project Timeline

- Project Proposal due: ~~Mar. 29th~~ Apr. 1st
- Project Presentations / Demos: Last Week of Class (May 3rd and 5th)
- Final Report due: May 11th

The rest of the semester...

- 3D Vision – processing point-cloud data from the kinect
- Multiple ways to control the robot:
  - Low-level velocity commands
  - **2D navigation goals**
  - High-level logical goals (e.g., “go to room 3.414”)

The rest of the semester...(con't)

- Human-Robot Interaction:
  - How the robot sees people
  - How the robot can interact with people (e.g., text to speech, gui, etc.)
- Learning and AI
  - Introduction to machine learning (ML)
  - How can the robot use ML to classify things and/or predict what will happen in the future

Installing our code base

- Github page:
  - https://github.com/utexas-bwi/bwi

Theories of Vision

Reading Discussion

“How does the conversion of analog to digital image take place?”

Reading Discussion

“How does the conversion of analog to digital image take place?”

“Do the gray values change in any way with newer cameras that are able to take clearer pictures? I know the amount of pixels increases.”

Reading Discussion

“I thought that the object level computation in an image posing a catch-22 situation was interesting. I would like to learn more about the criteria of how researchers clump points into objects based on their characteristics.”

Reading Discussion

“How relevant is the philosophical aspect of seeing, or the “visual experience”? For example, the paper talks about “qualia,” which are “intrinsic” properties of the something, as opposed to representational or functional features. The paper makes a good point that they are hard to quantify, but are they completely useless? Is there no use for the subjectivity of one’s experience with some event?”

Reading for next week...

- “Rusu, Radu Bogdan, and Steve Cousins. "3d is here: Point cloud library (pcl)." Robotics and Automation (ICRA), 2011 IEEE International Conference on. IEEE, 2011.”

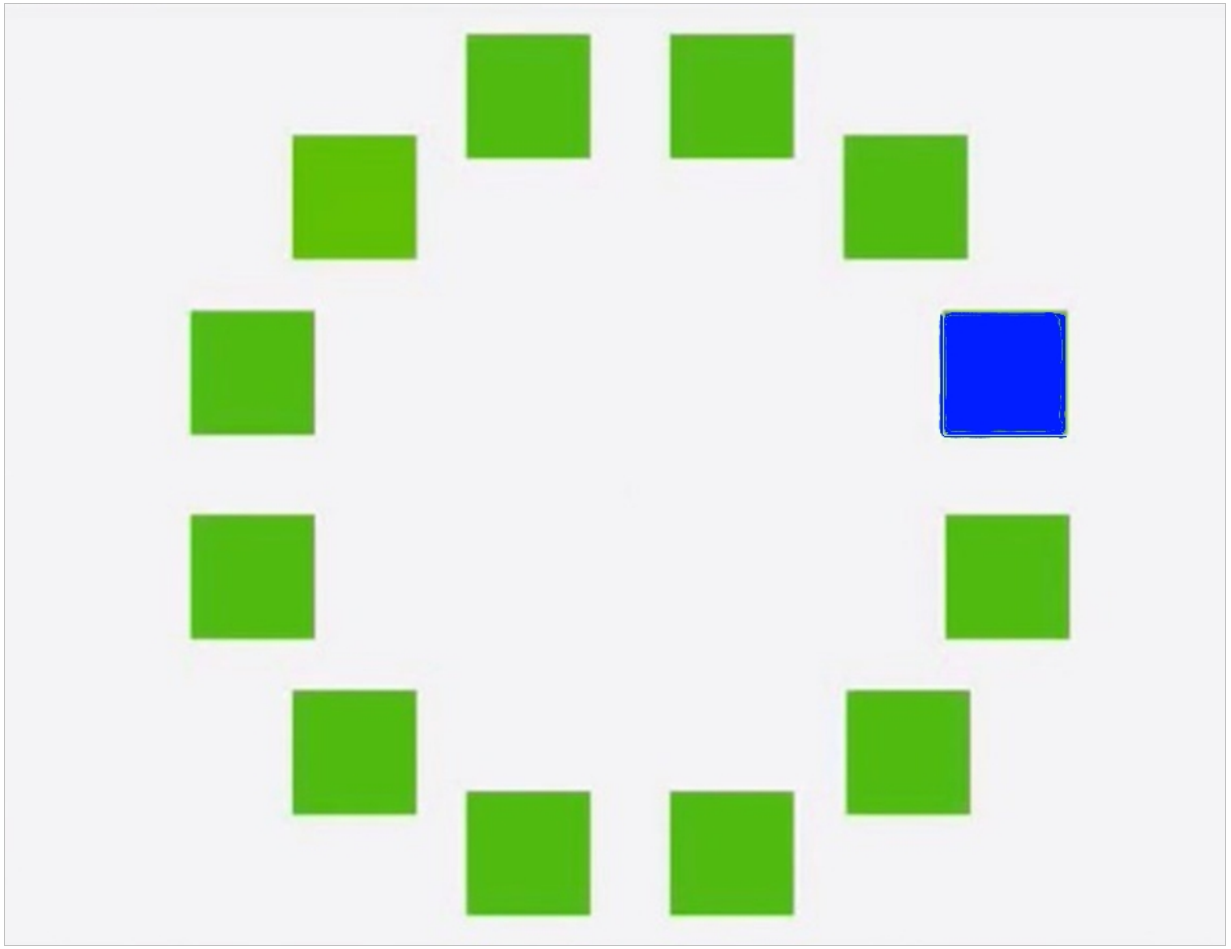
- “Tutorial: Point Cloud Library – USC Robotics Research Lab”

Theories of Vision

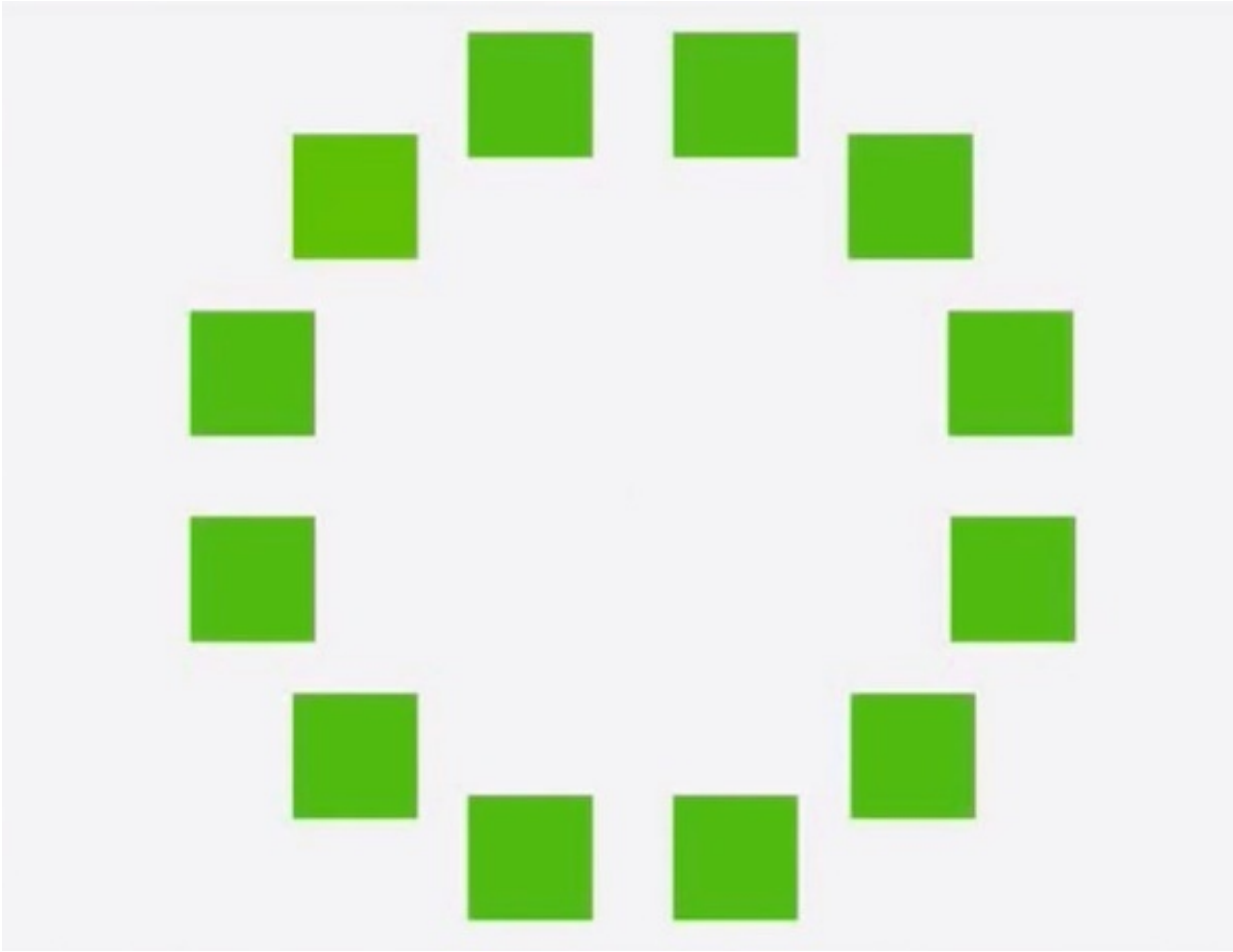
Main Reference

- J. K. O'Regan and A. Noe, (2001). ``A sensorimotor account of vision and visual consciousness'' , *Behavioral and Brain Sciences*, 24(5), 939- 1011.

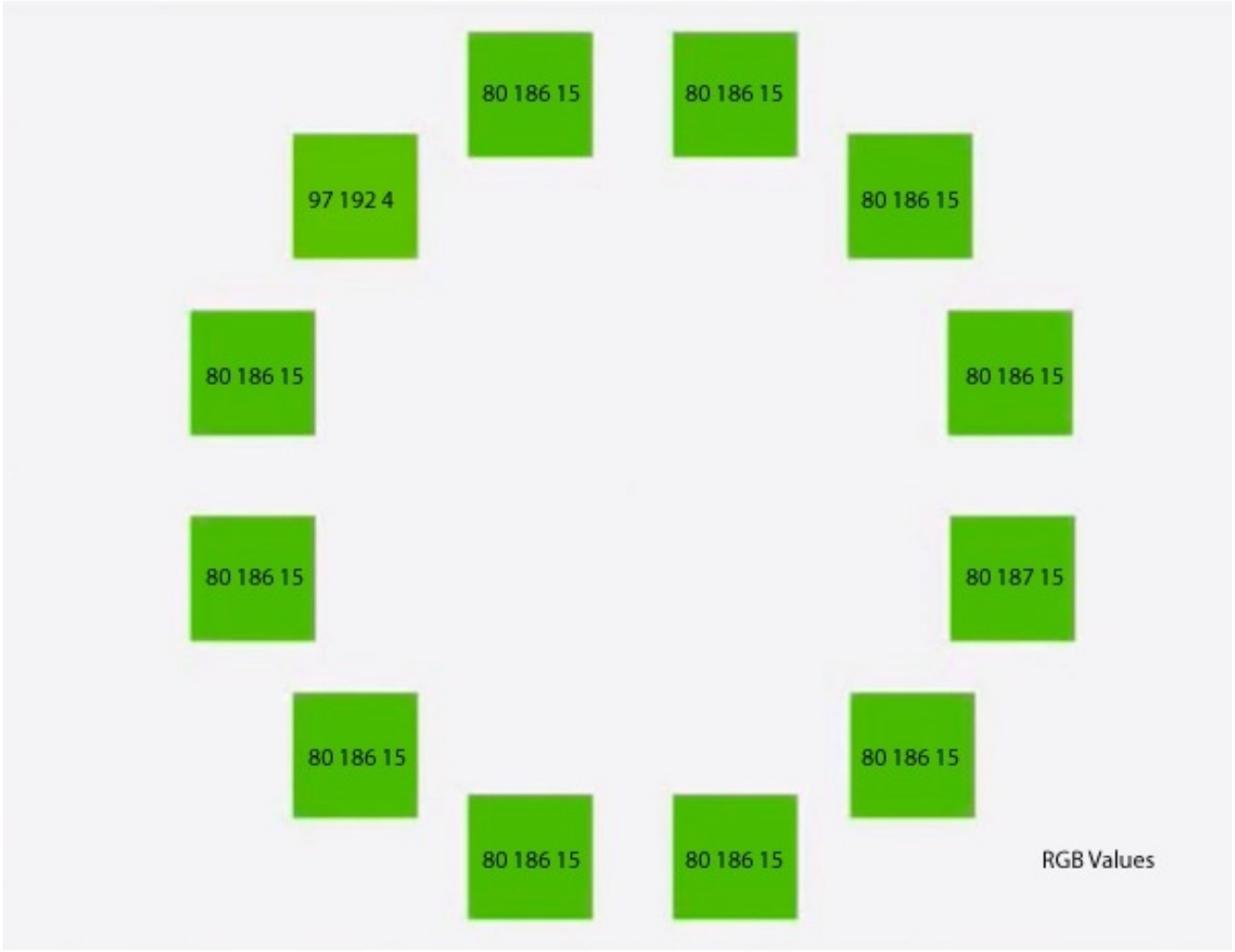
Can you spot the different color?



Can you spot the different color?



Can you spot the different color?



BASIC COLOR TERMS
Their Universality and Evolution

BRENT BERLIN AND PAUL KAY

THE DAVID HUME SERIES
PHILOSOPHY AND COGNITIVE SCIENCE REISSUES

CSLI PUBLICATIONS

The 22 Actually Occurring Types of Basic Color Lexicon

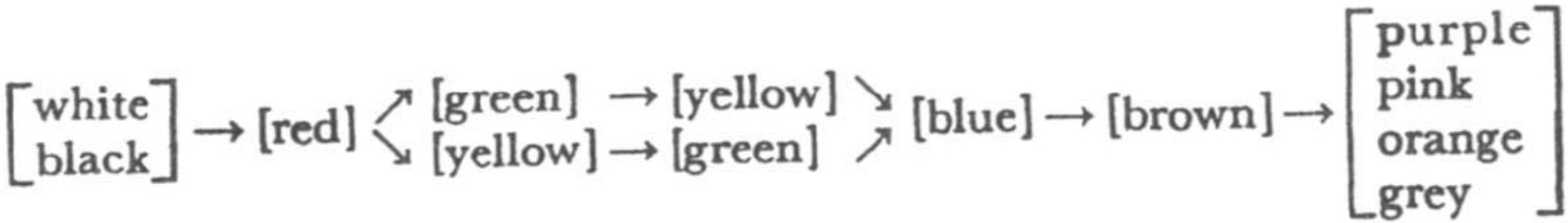
Type	No. of basic color terms	Perceptual categories encoded in the basic color terms										
		white	black	red	green	yellow	blue	brown	pink	purple	orange	grey
1	2	+	+	−	−	−	−	−	−	−	−	−
2	3	+	+	+	−	−	−	−	−	−	−	−
3	4	+	+	+	+	−	−	−	−	−	−	−
4	4	+	+	+	−	+	−	−	−	−	−	−
5	5	+	+	+	+	+	−	−	−	−	−	−
6	6	+	+	+	+	+	+	−	−	−	−	−
7	7	+	+	+	+	+	+	+	−	−	−	−
8	8	+	+	+	+	+	+	+	+	−	−	−
9	8	+	+	+	+	+	+	+	−	+	−	−
10	8	+	+	+	+	+	+	+	−	−	+	−
11	8	+	+	+	+	+	+	+	−	−	−	+
12	9	+	+	+	+	+	+	+	+	+	−	−
13	9	+	+	+	+	+	+	+	+	−	+	−
14	9	+	+	+	+	+	+	+	+	−	−	+
15	9	+	+	+	+	+	+	+	−	+	+	−
16	9	+	+	+	+	+	+	+	−	+	−	+
17	9	+	+	+	+	+	+	+	−	−	+	+
18	10	+	+	+	+	+	+	+	+	+	+	−
19	10	+	+	+	+	+	+	+	+	+	−	+
20	10	+	+	+	+	+	+	+	+	−	+	+
21	10	+	+	+	+	+	+	+	−	+	+	+
22	11	+	+	+	+	+	+	+	+	+	+	+

NOTE: Only these twenty-two out of the logically possible 2,048 combinations of the eleven basic color categories are found.

[From “Basic Color Terms”]

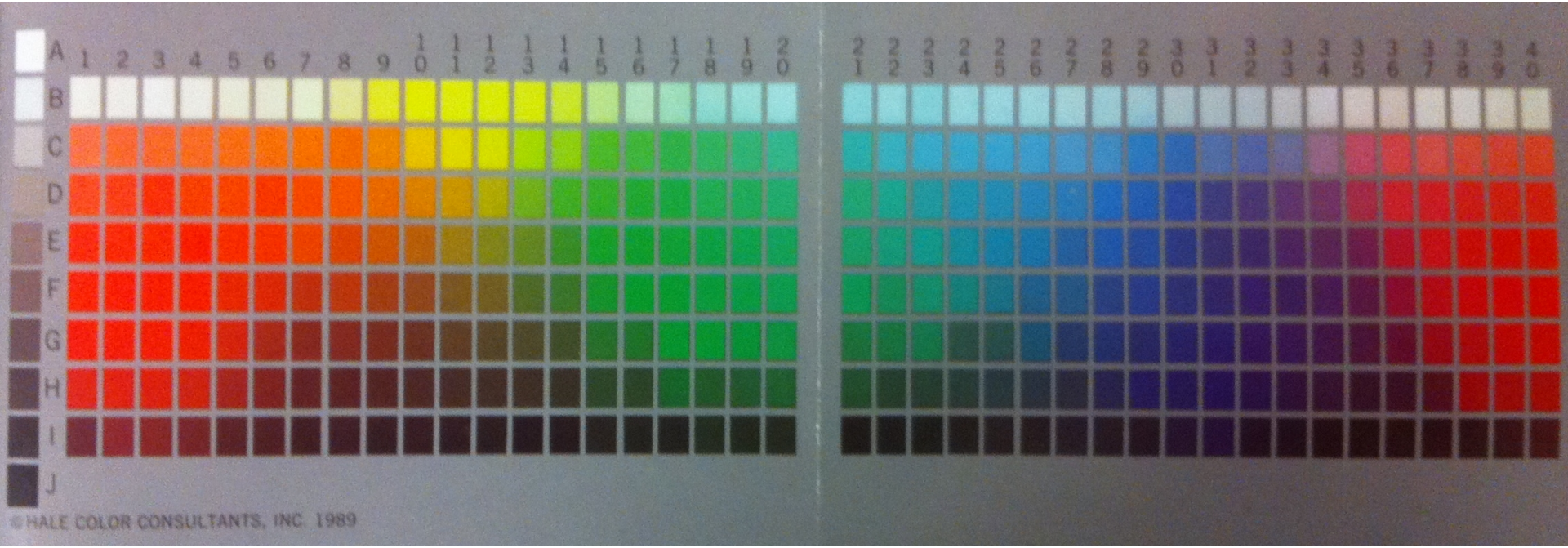
$$\begin{bmatrix}\text{white}\\ \text{black}\end{bmatrix} < [\text{red}] < \begin{bmatrix}\text{green}\\ \text{yellow}\end{bmatrix} < [\text{blue}] < [\text{brown}] < \begin{bmatrix}\text{purple}\\ \text{pink}\\ \text{orange}\\ \text{grey}\end{bmatrix}$$

[From “Basic Color Terms”]



[From “Basic Color Terms”]

Color Chart Used in the Survey



[From “Basic Color Terms”]

Color Terms in 20 Languages

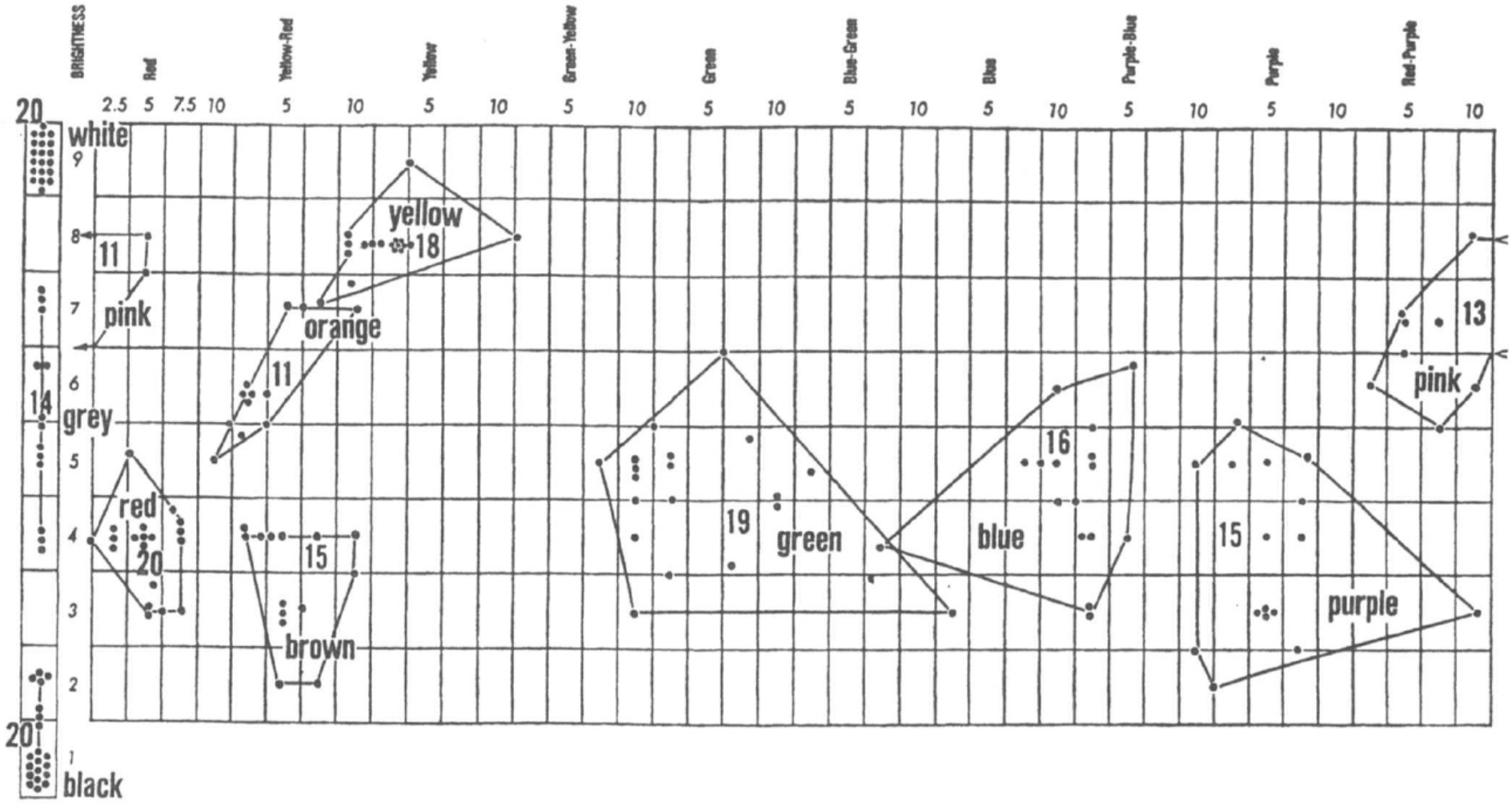


FIGURE 3. NORMALIZED FOCI OF BASIC COLOR TERMS IN TWENTY LANGUAGES. NOTE: Numerals appearing along the borders of the chart refer to the Munsell system of color notation. Numerals appearing on the body of the chart refer to the number of languages in the sample of twenty which encode the corresponding color category. The smallest possible number of lines are used to enclose each color area.

[From “Basic Color Terms”]

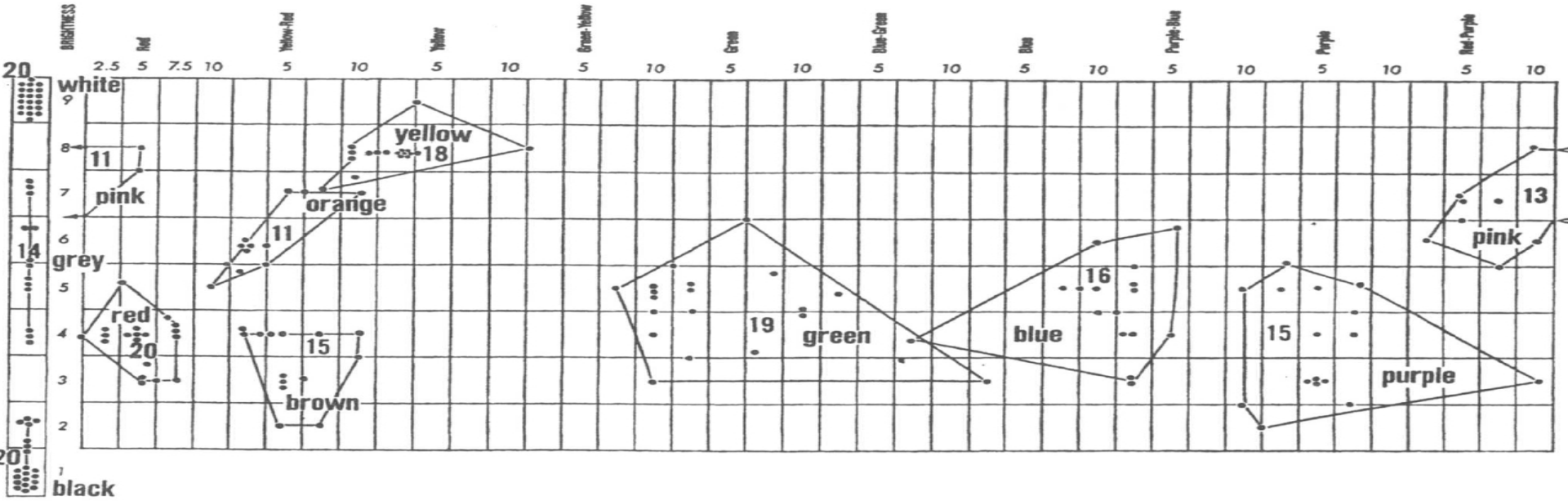
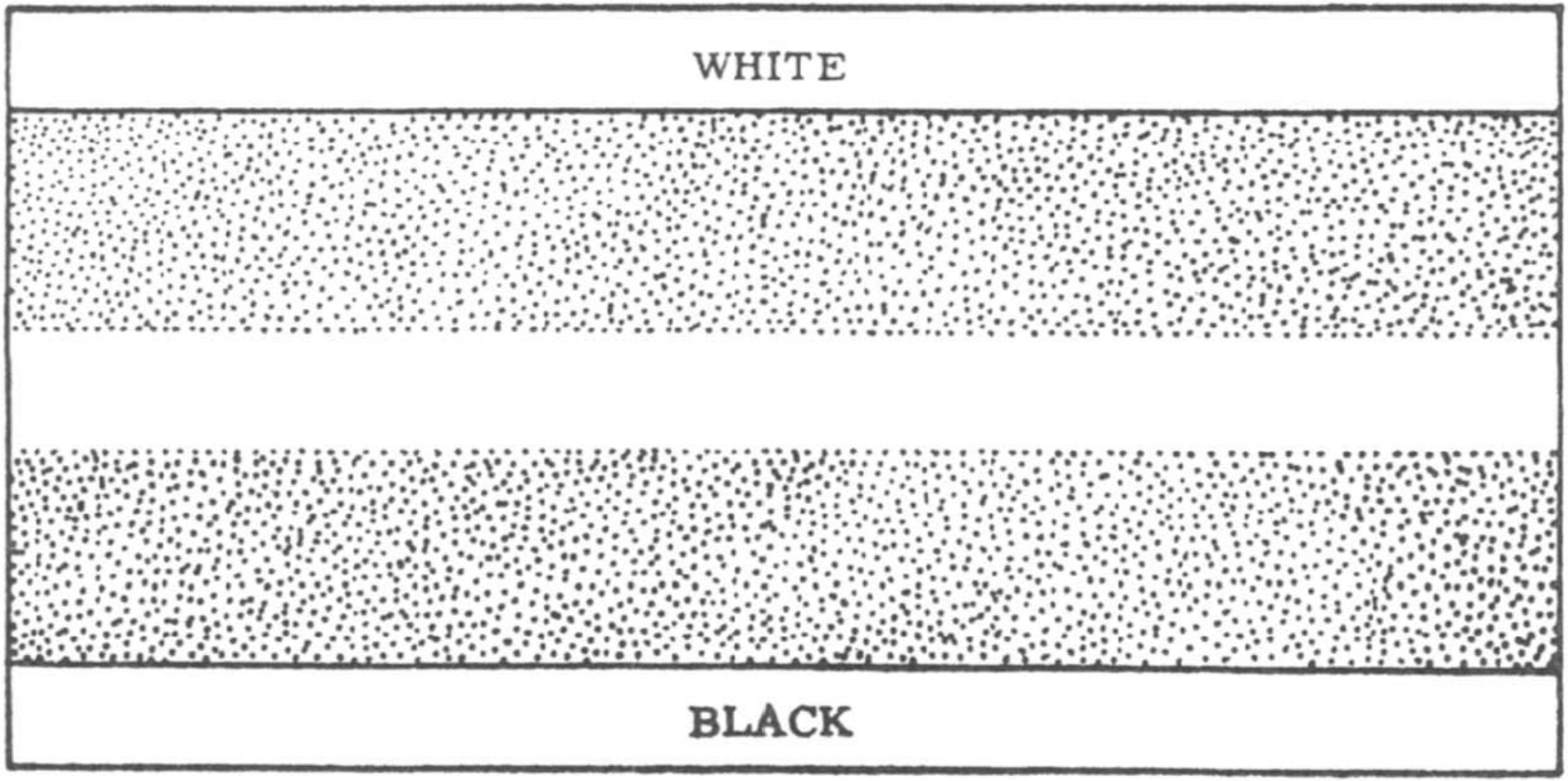


FIGURE 3. NORMALIZED FOCI OF BASIC COLOR TERMS IN TWENTY LANGUAGES. NOTE: Numerals appearing along the borders of the chart refer to the Munsell system of color notation. Numerals appearing on the body of the chart refer to the number of languages in the sample of twenty which encode the corresponding color category. The smallest possible number of lines are used to enclose each color area.

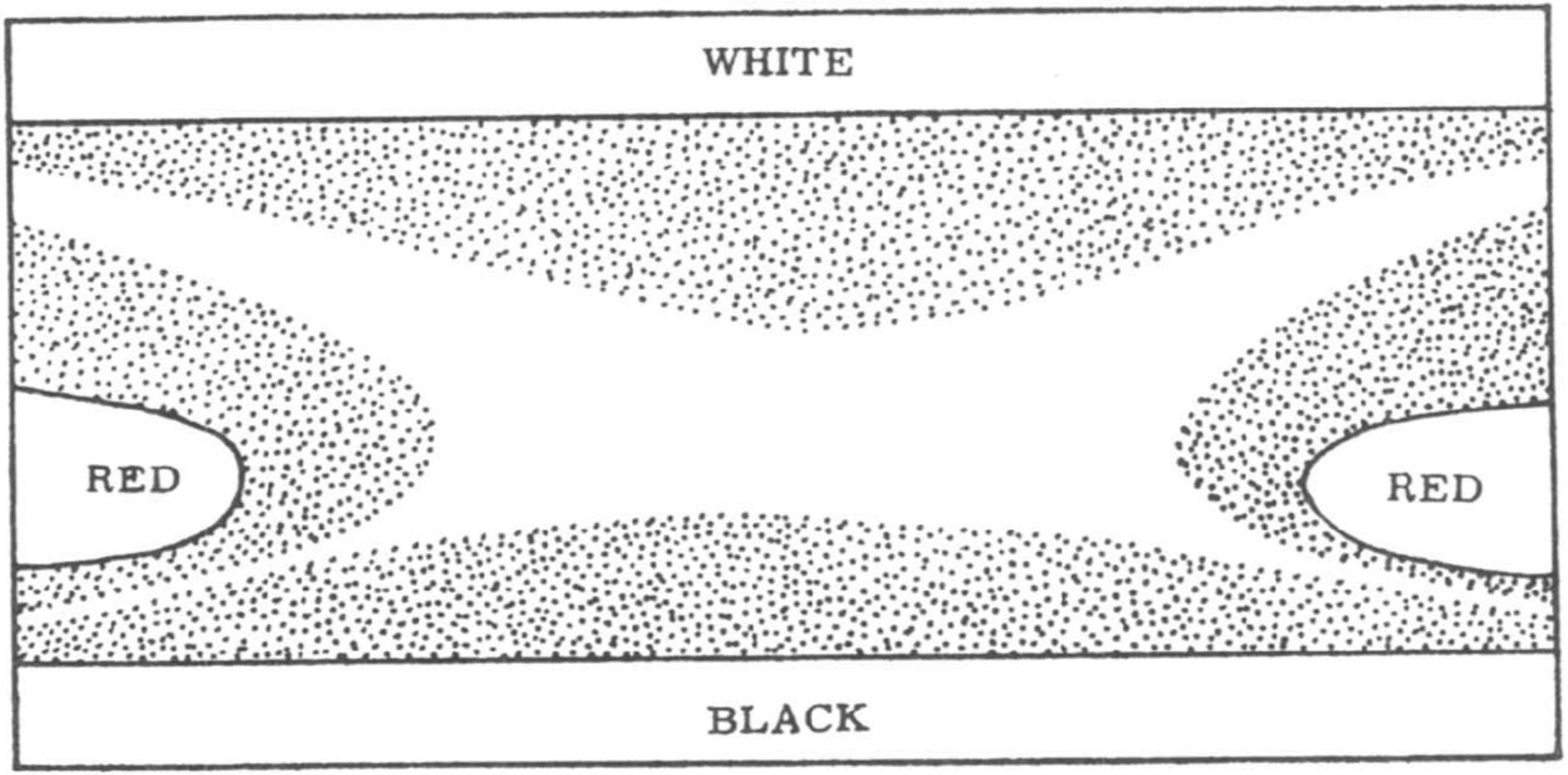
[From “Basic Color Terms”]

Typical Stage I



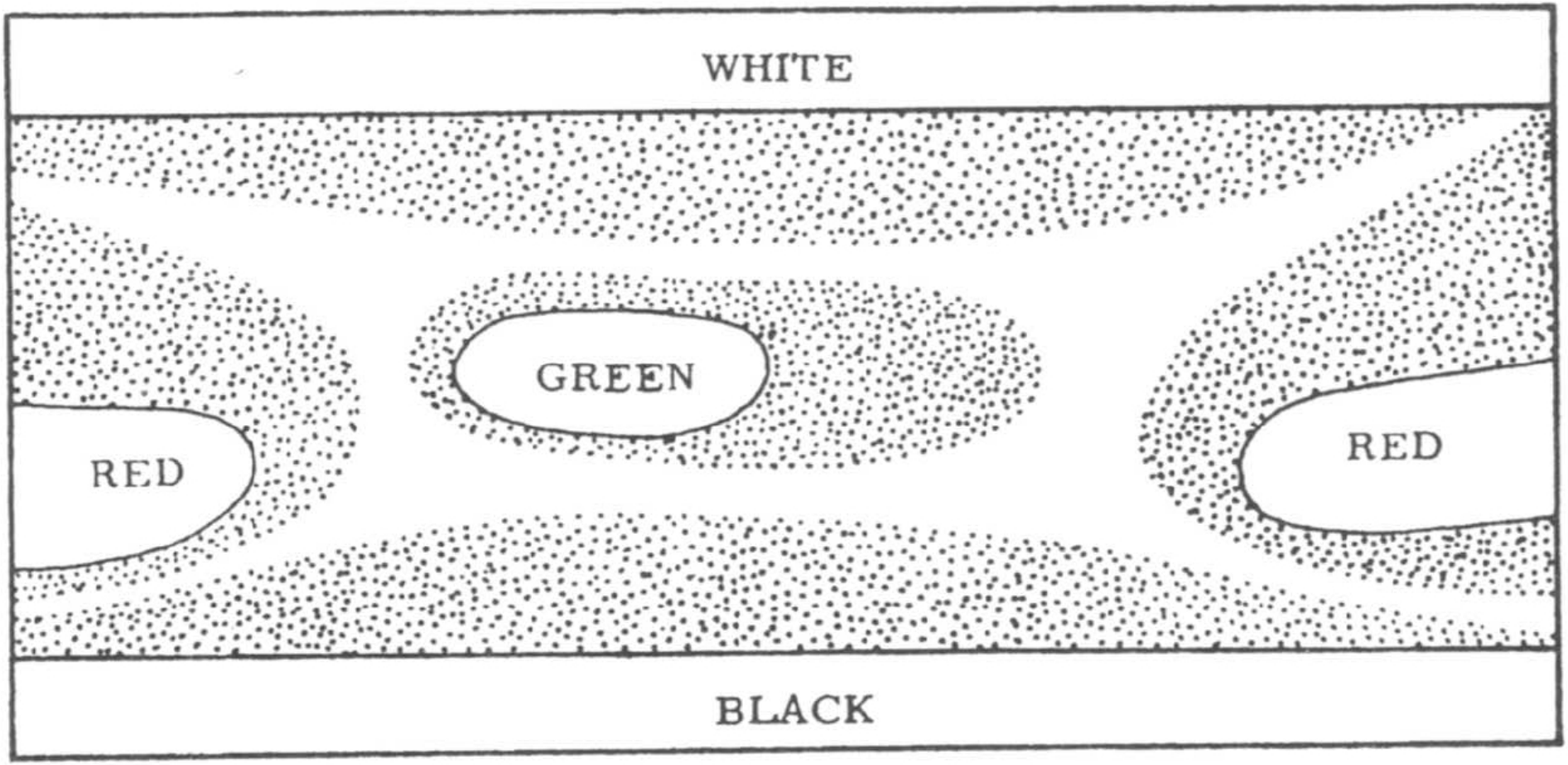
[From “Basic Color Terms”]

Typical Stage II



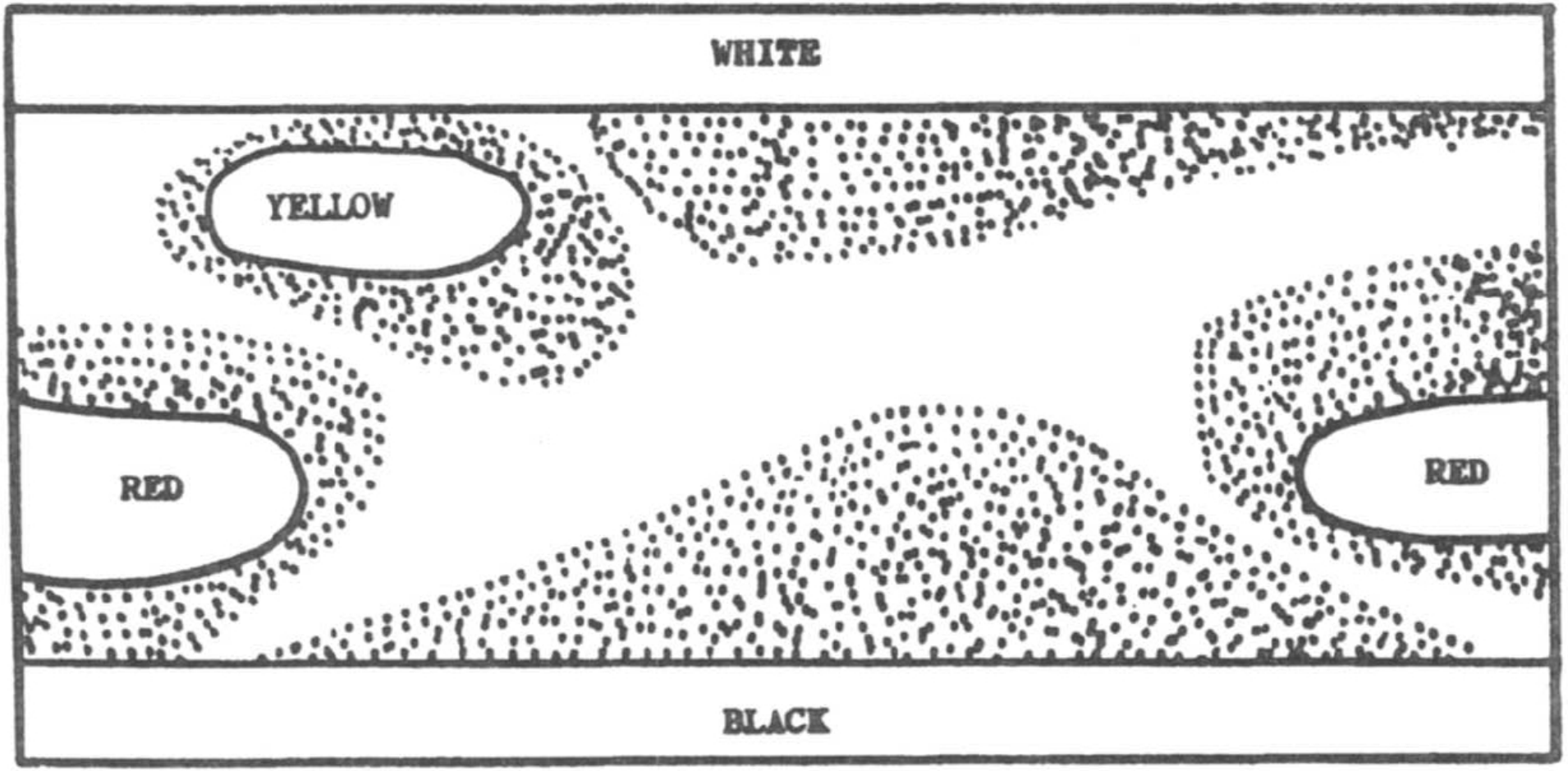
[From “Basic Color Terms”]

Typical Stage III.a



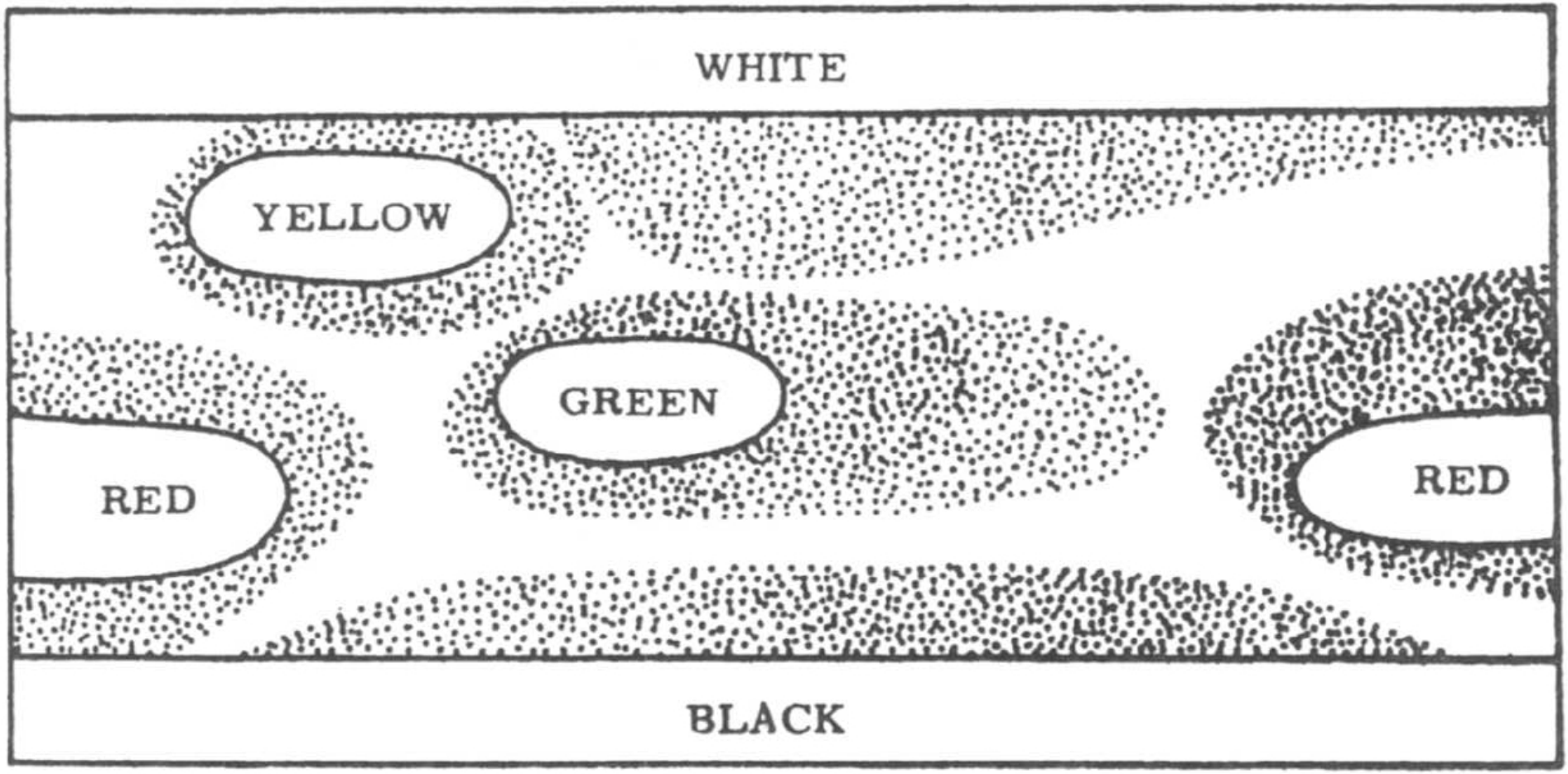
[From “Basic Color Terms”]

Typical Stage III.b



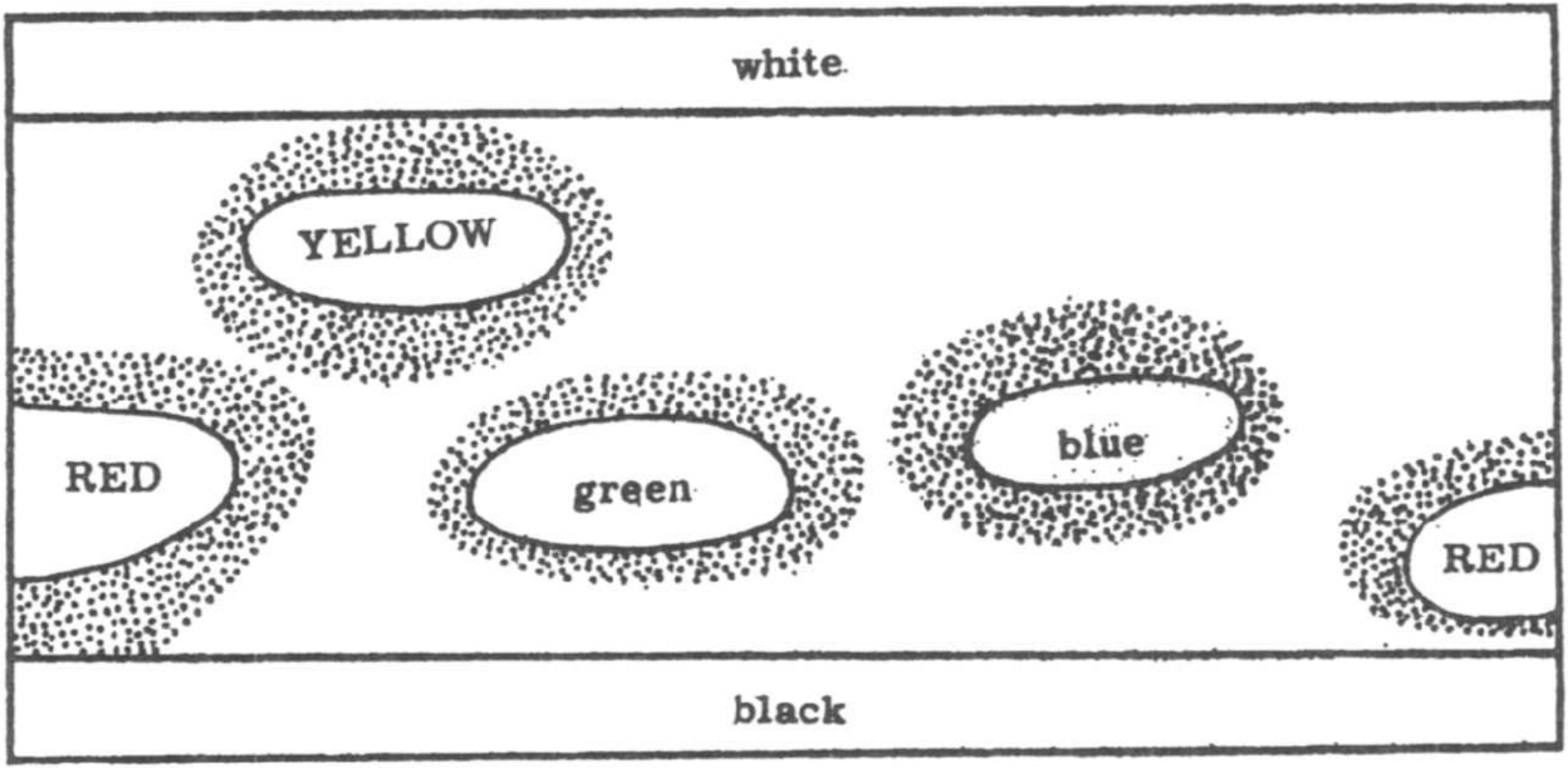
[From “Basic Color Terms”]

Typical Stage IV



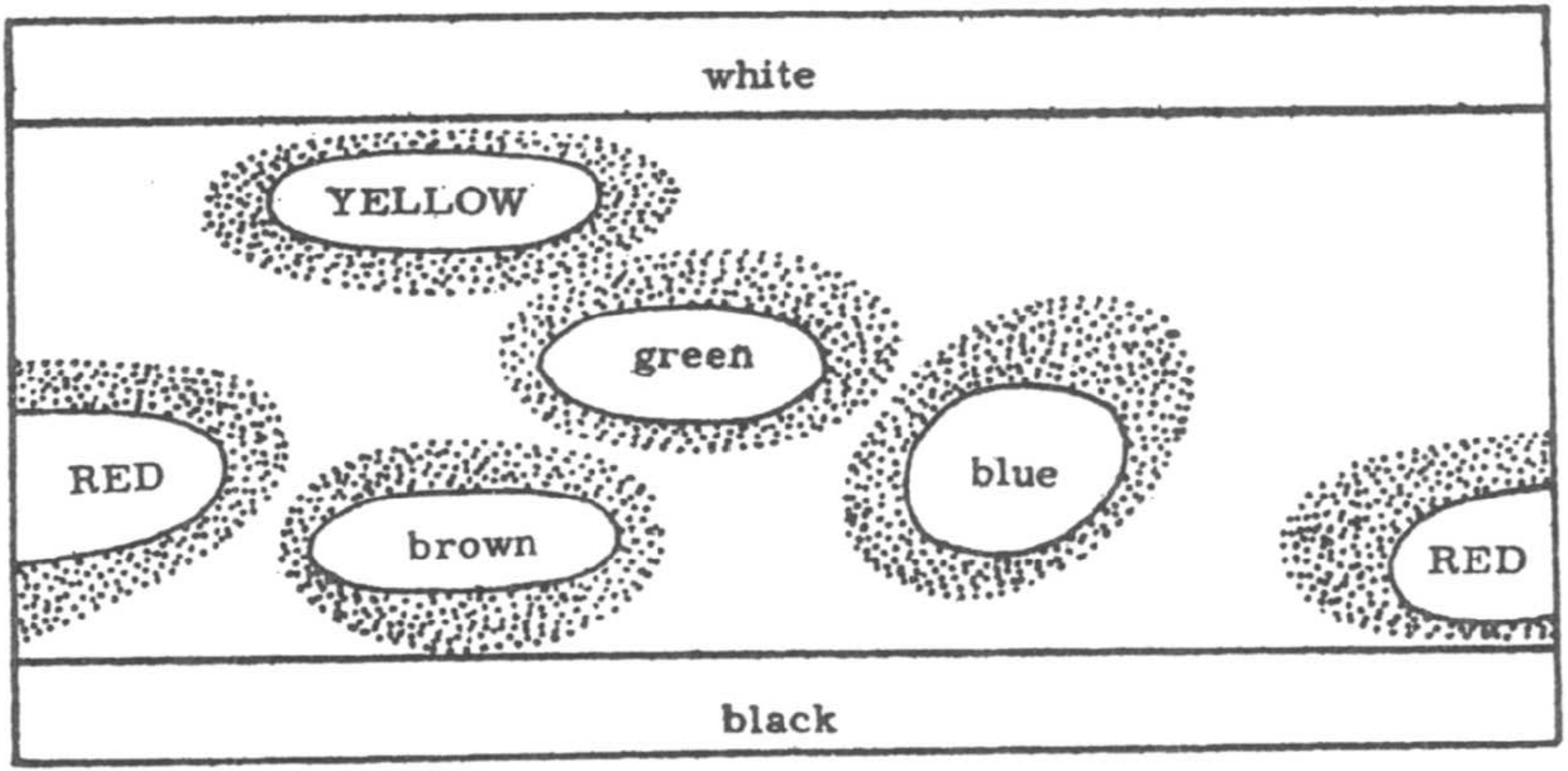
[From “Basic Color Terms”]

Typical Stage V



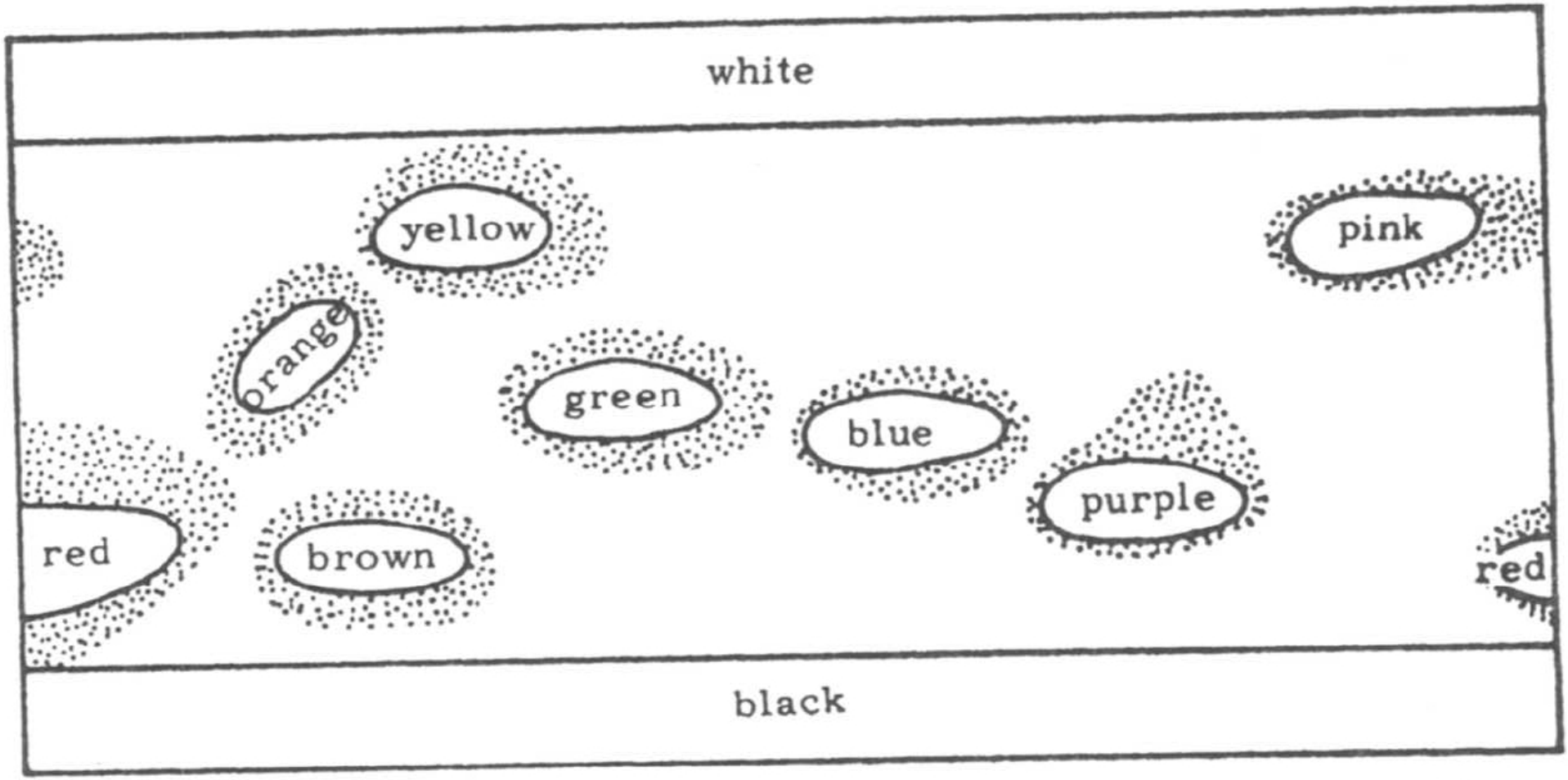
[From “Basic Color Terms”]

Typical Stage VI



[From “Basic Color Terms”]

Typical Stage VII



[From “Basic Color Terms”]

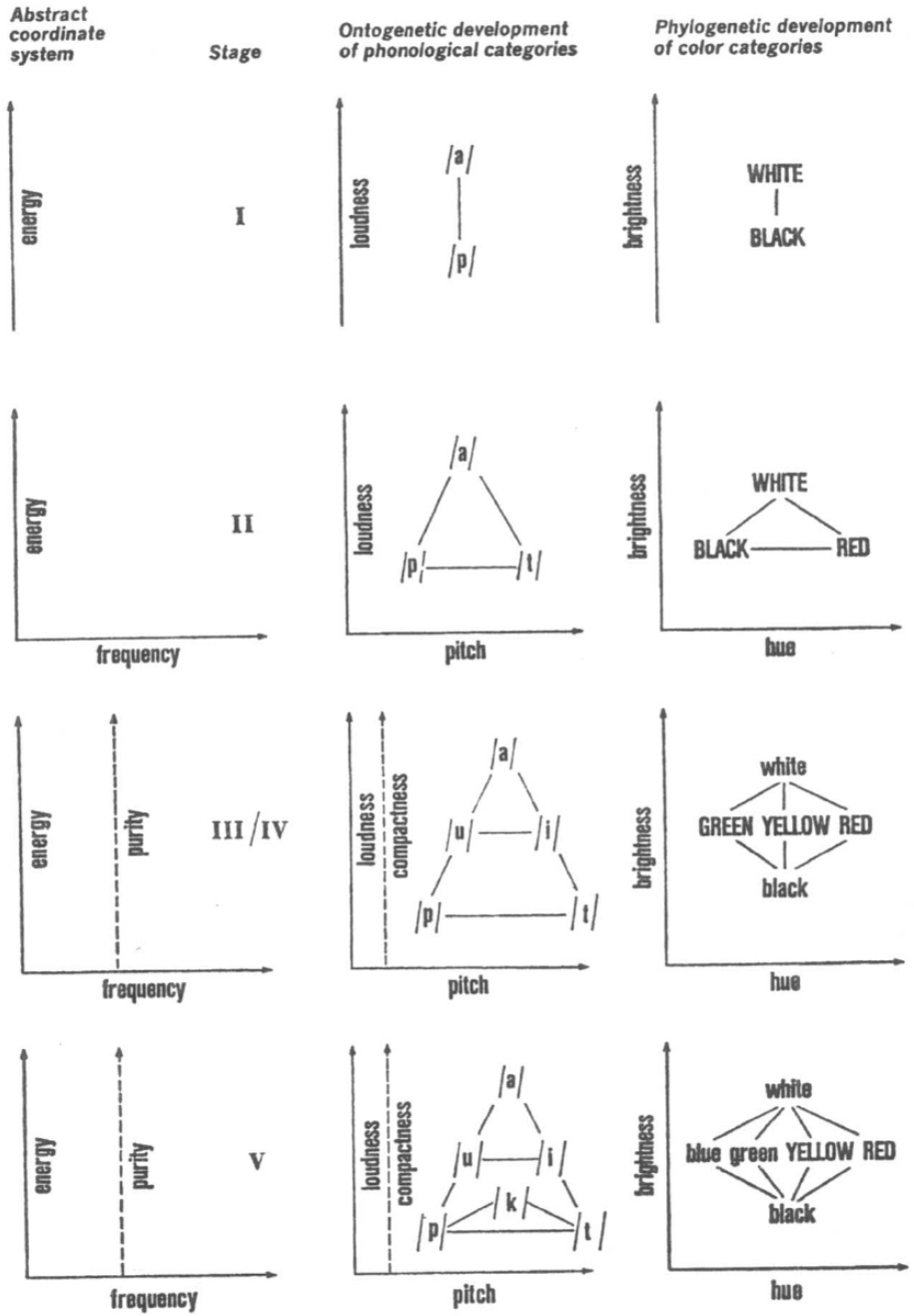
Summary

Stage I	BLACK, WHITE (two terms)
Stage II	BLACK, WHITE, RED (three terms)
Stage IIIa	BLACK, WHITE, RED, GREEN (extending into blues) (four terms)
Stage IIIb	BLACK, WHITE, RED, YELLOW (four terms)
Stage IV	BLACK, WHITE, RED, GREEN, YELLOW (five terms)
Stage V	black, white, RED, green, YELLOW, blue (six terms)
Stage VI	black, white, RED, green, YELLOW, blue, brown (seven terms)
Stage VII	black, white, red, green, yellow, blue, brown, purple, pink, orange, grey (eight, nine, ten, or eleven terms)

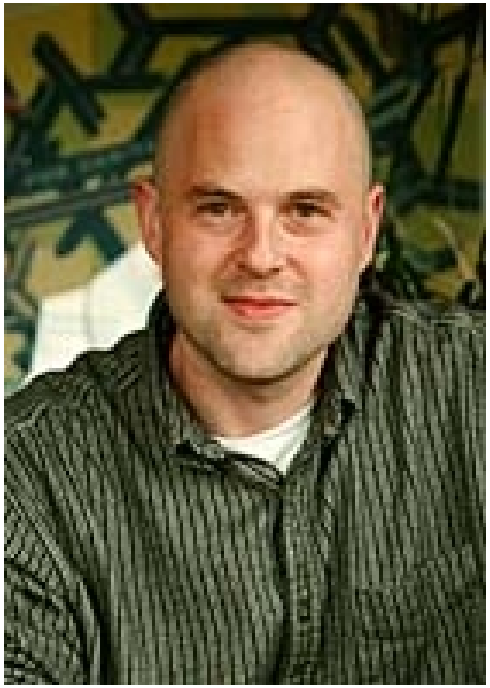
The Two Possible Temporal Orders Are:

and

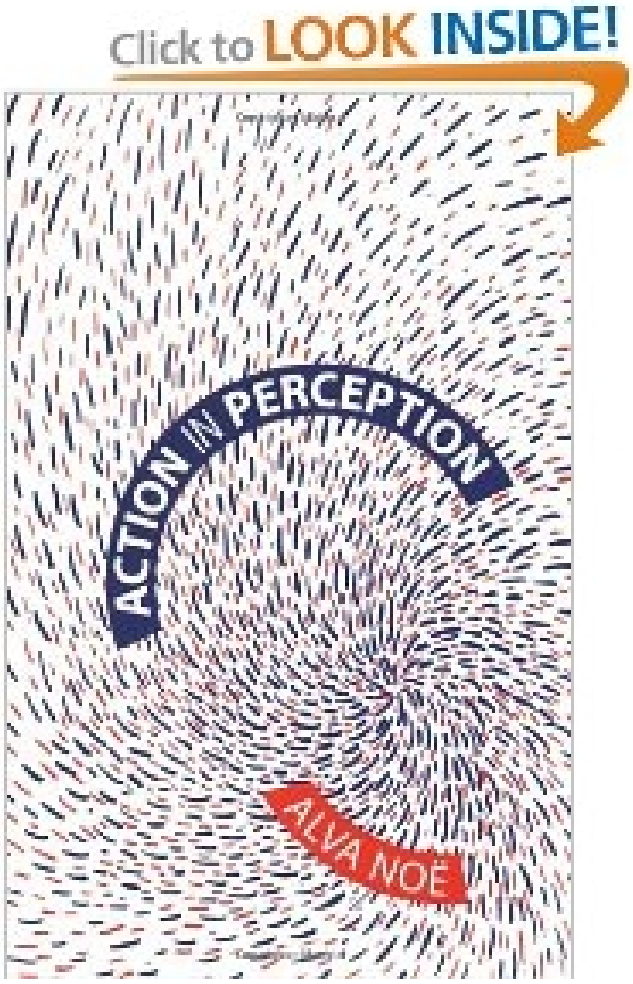
Parallels in Developmental Sequence of Phonological and Color Categories

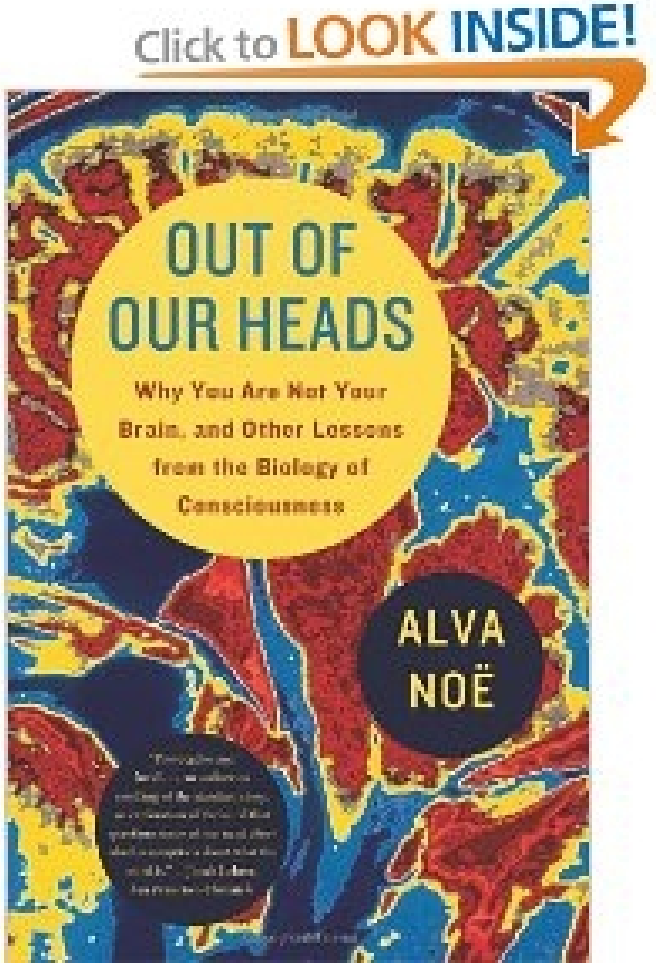


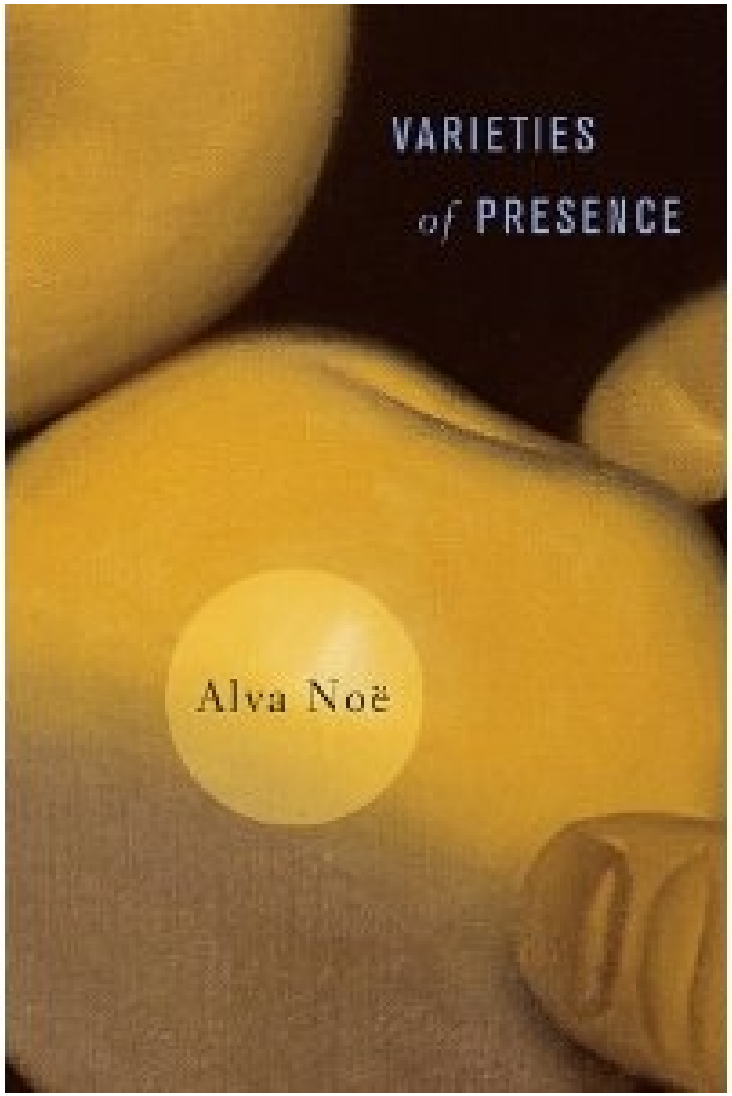
J. Kevin O'Regan and Alva Noë



Further Reading






VARIETIES
of PRESENCE
Alva Noë

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)

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

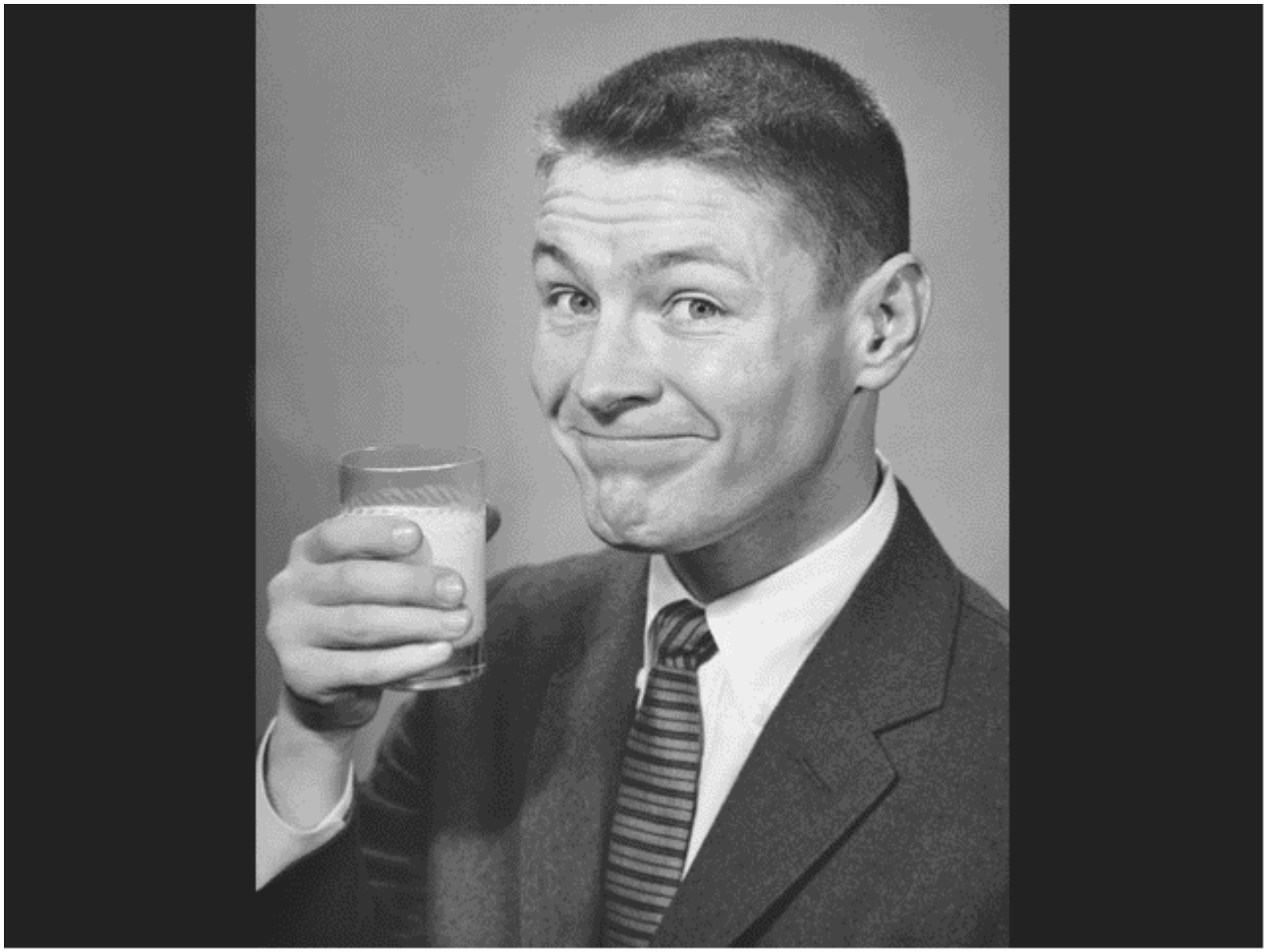
[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

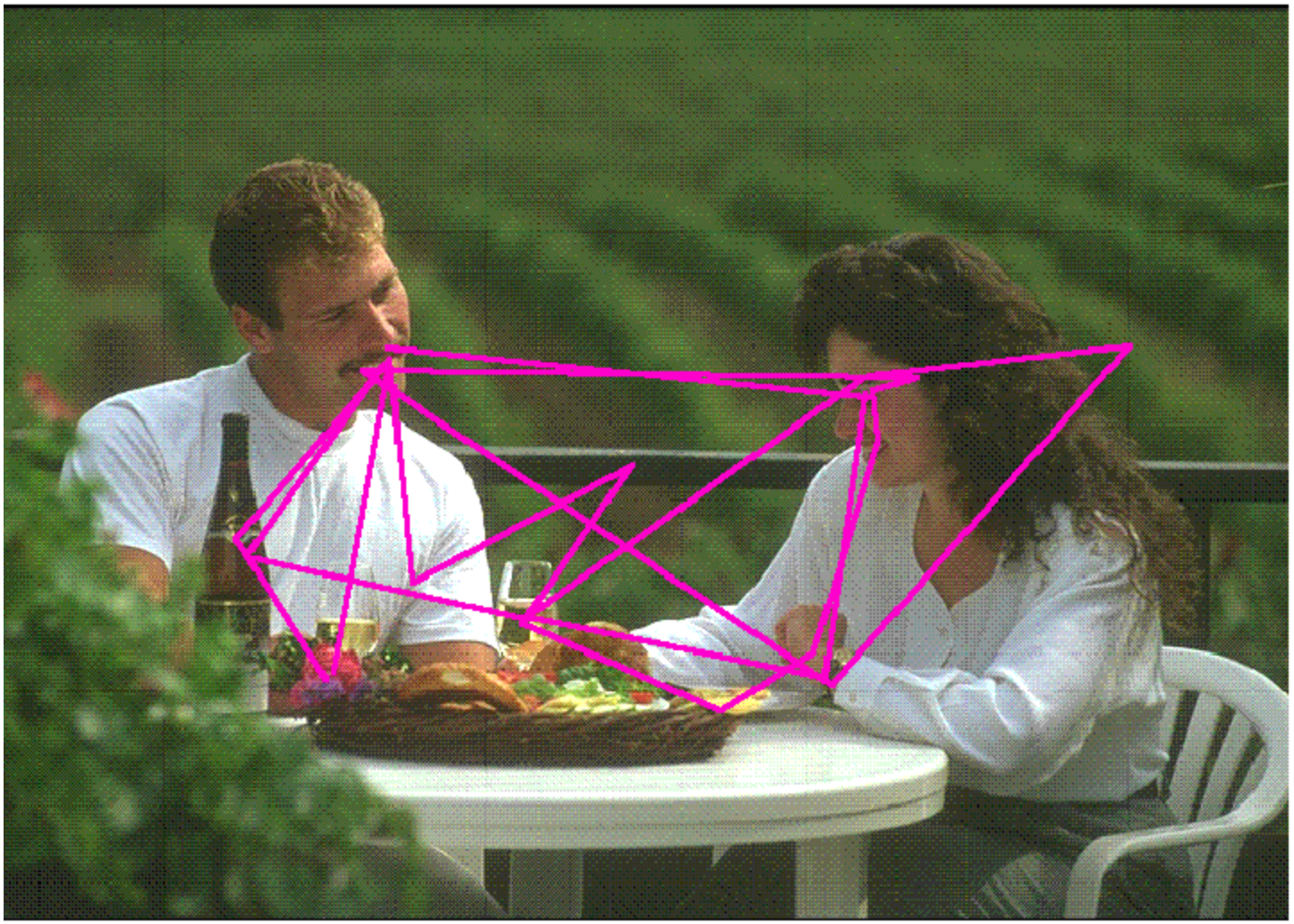
[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]



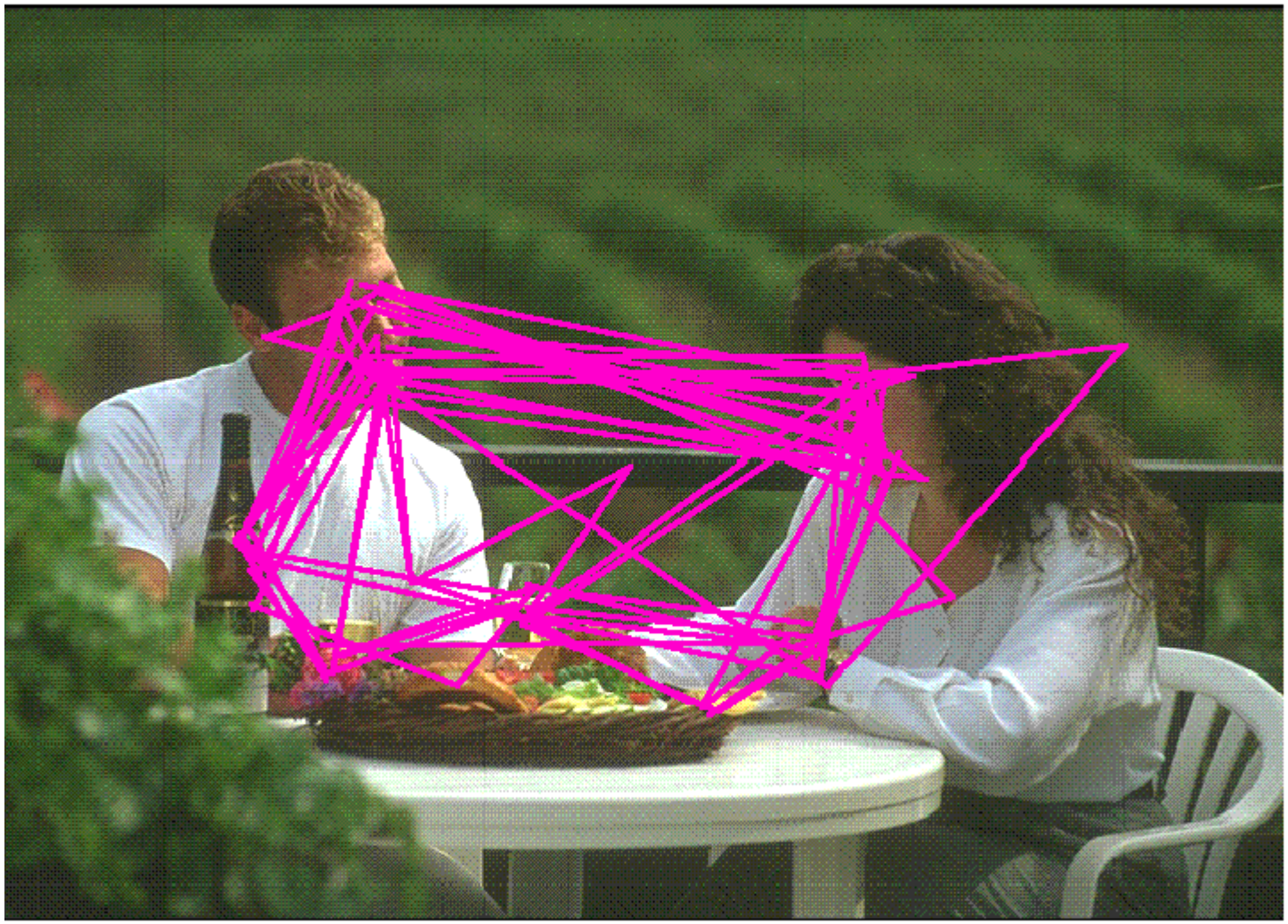
[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Scan Path



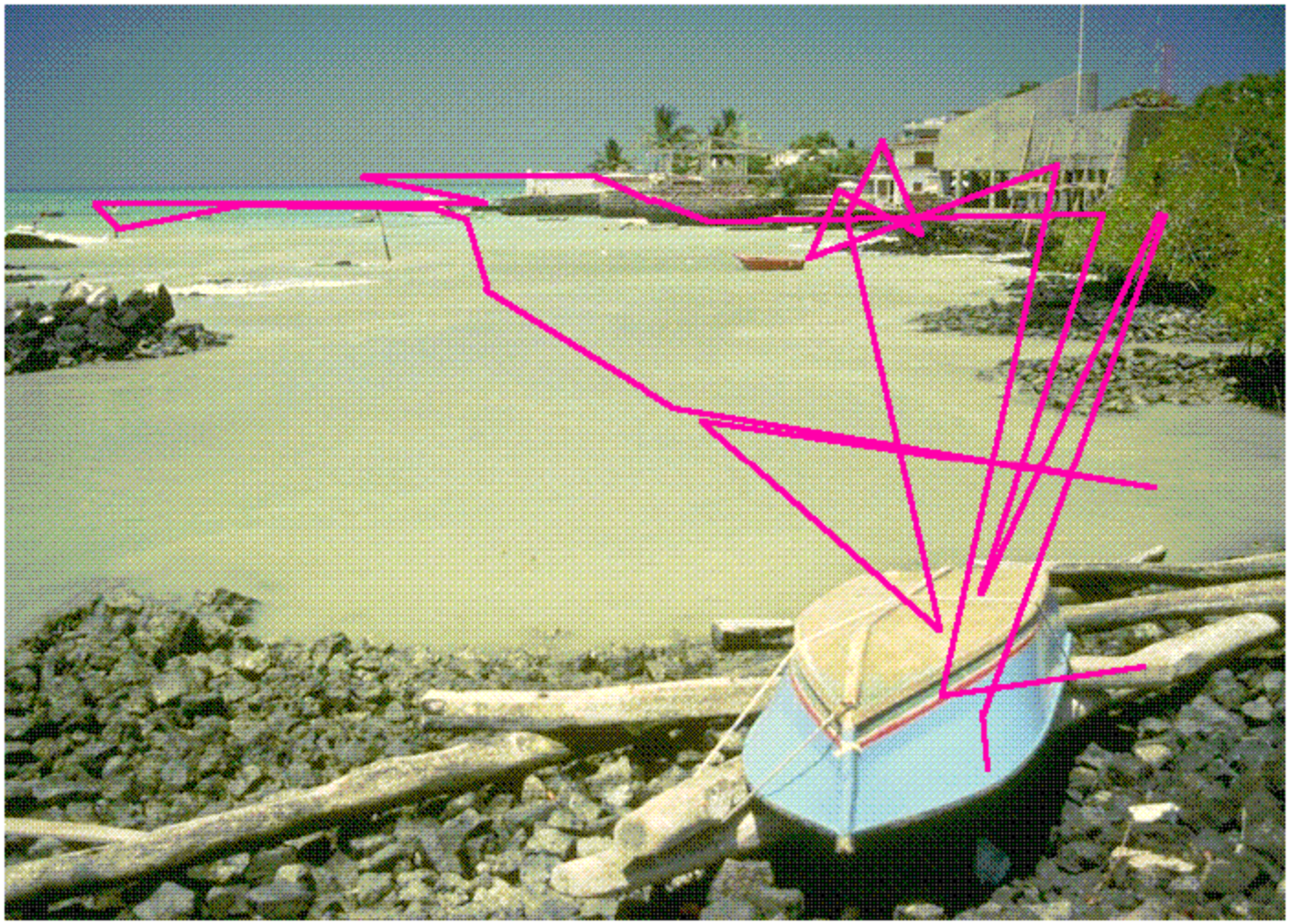
[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Even Longer Scan Path



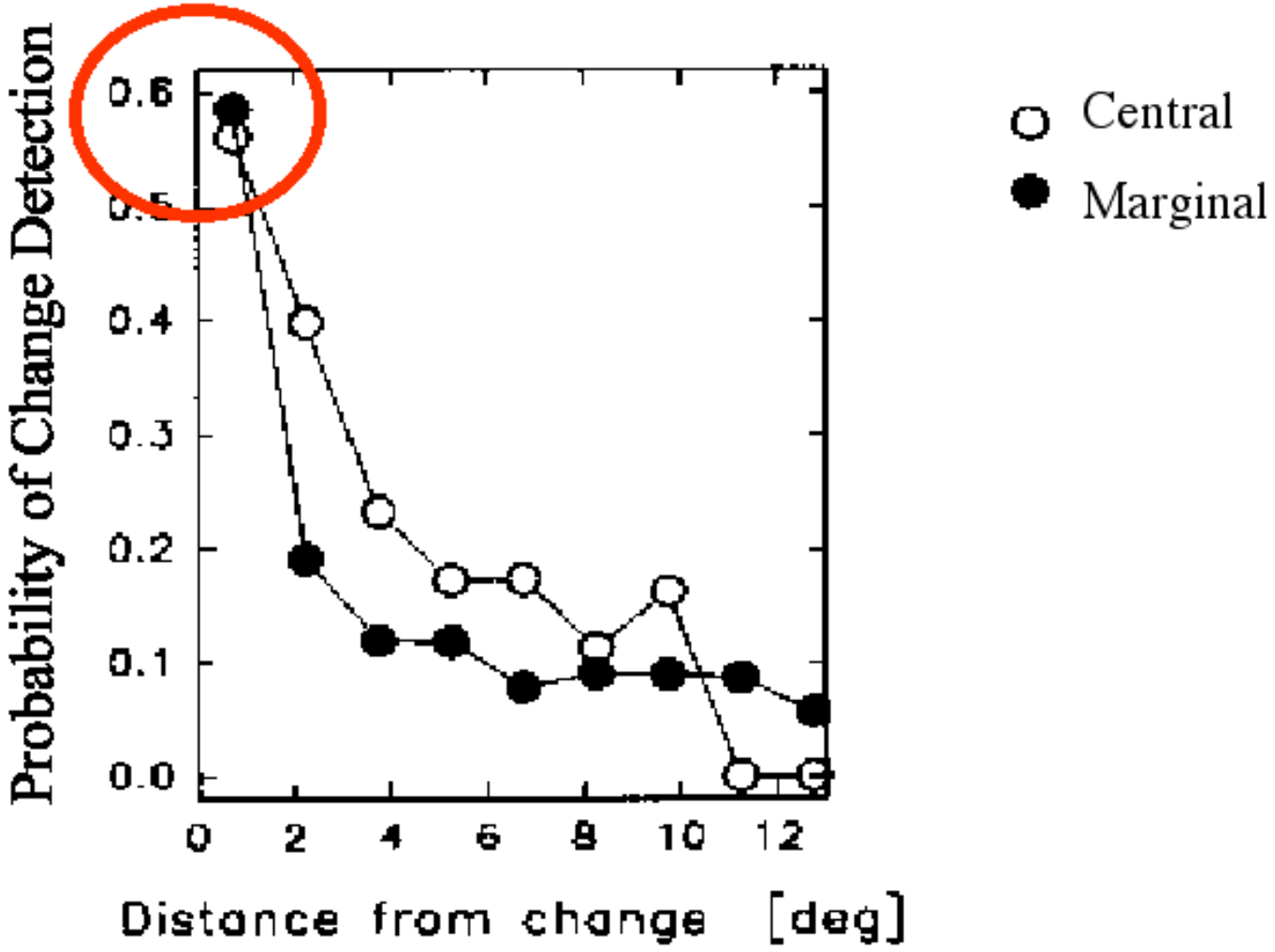
[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Another Example

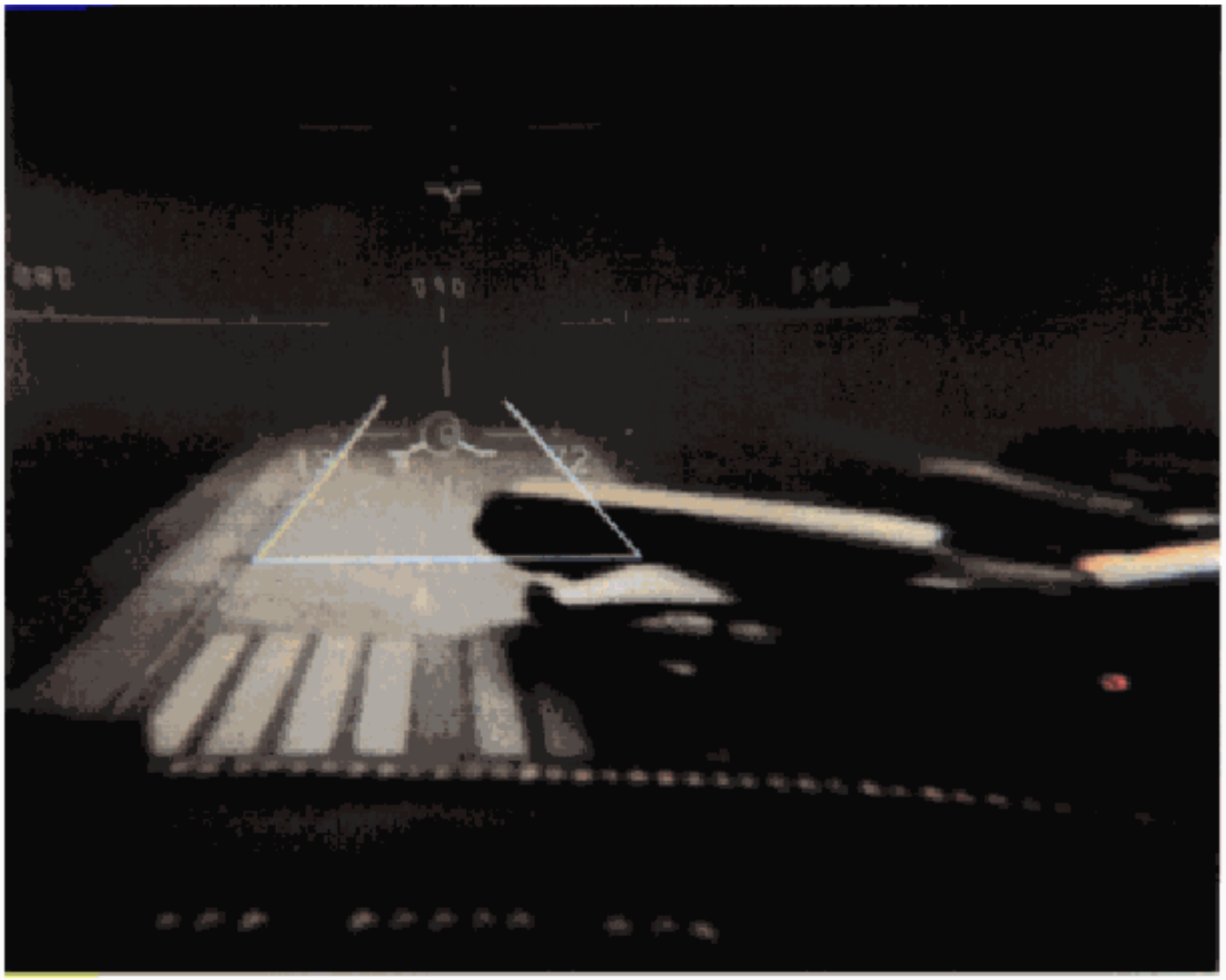


[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

O'Regan, Deubel, Clark & Rensink, 2000

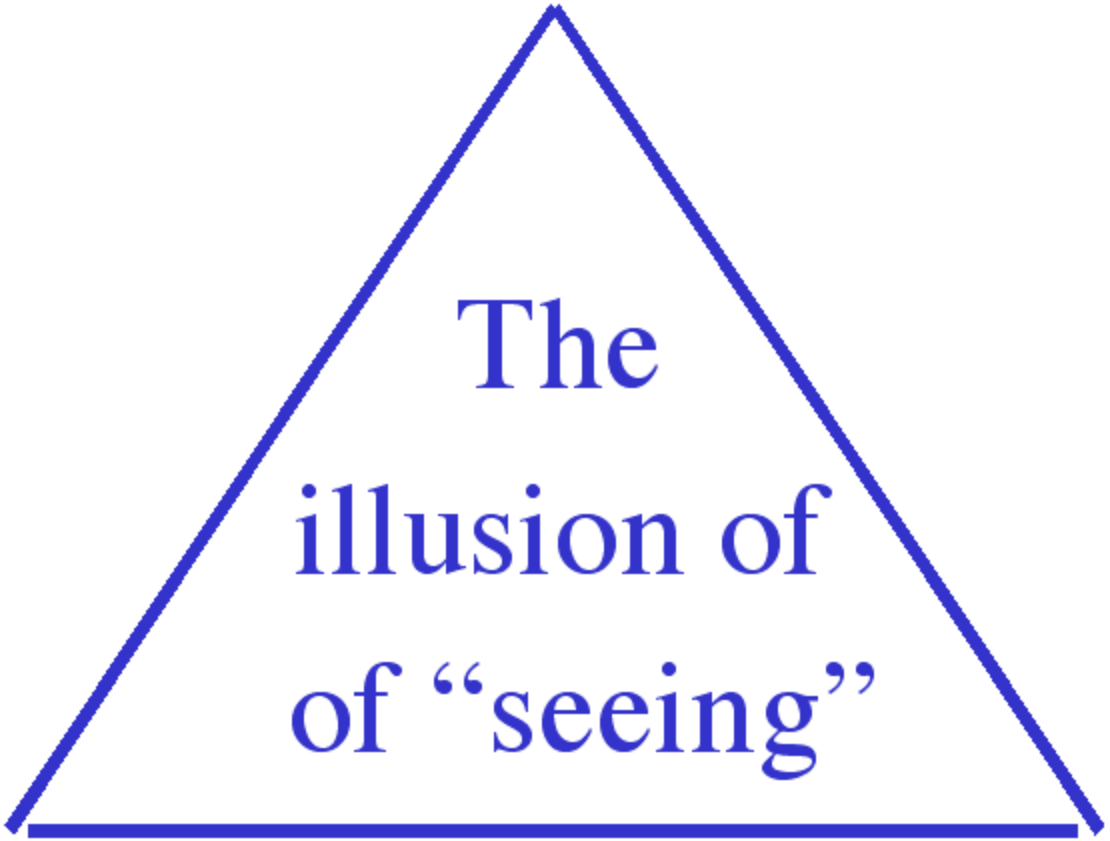


[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]



Haines, 1991. Ames Res. Center, NASA

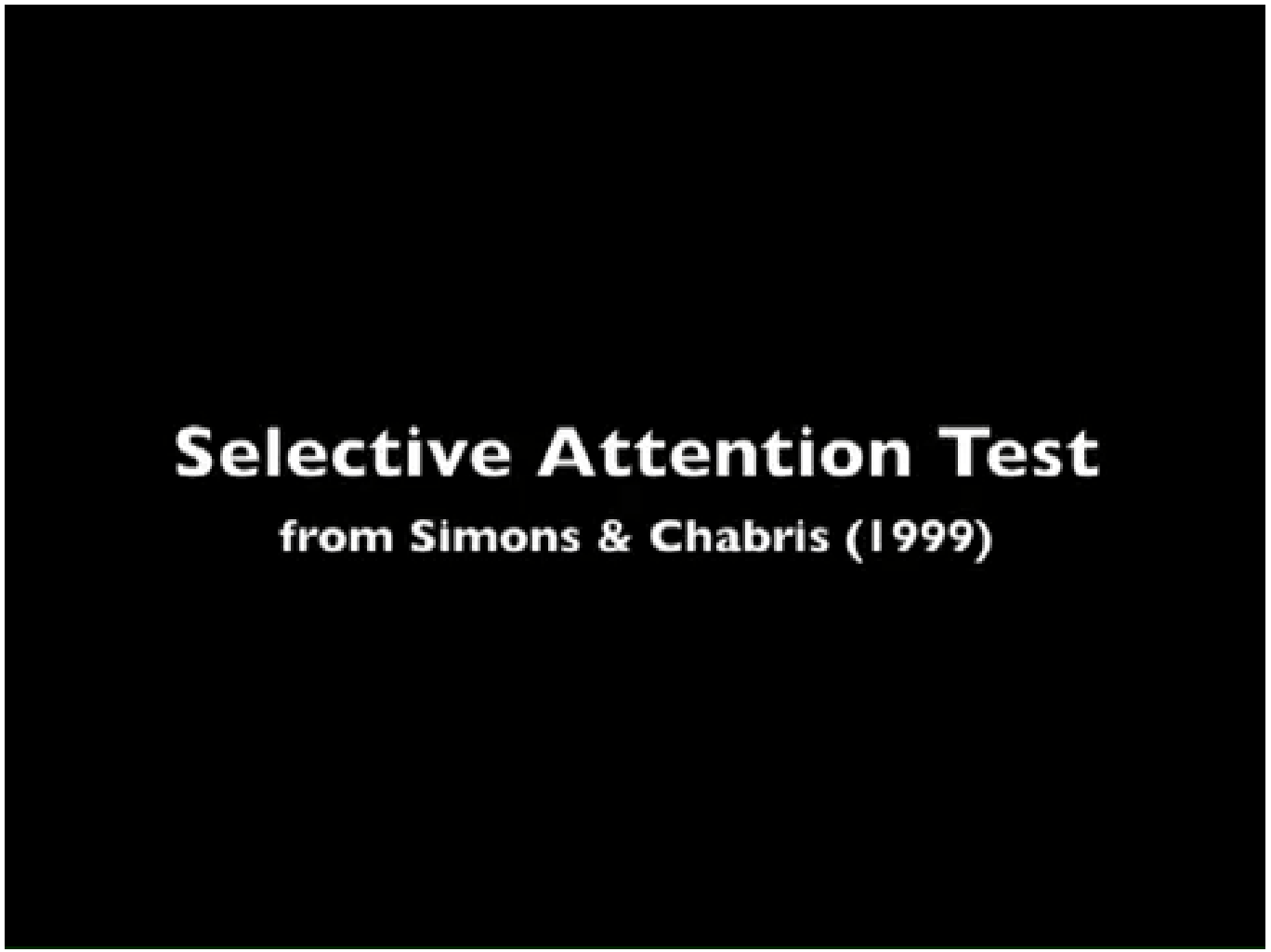
[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]



[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

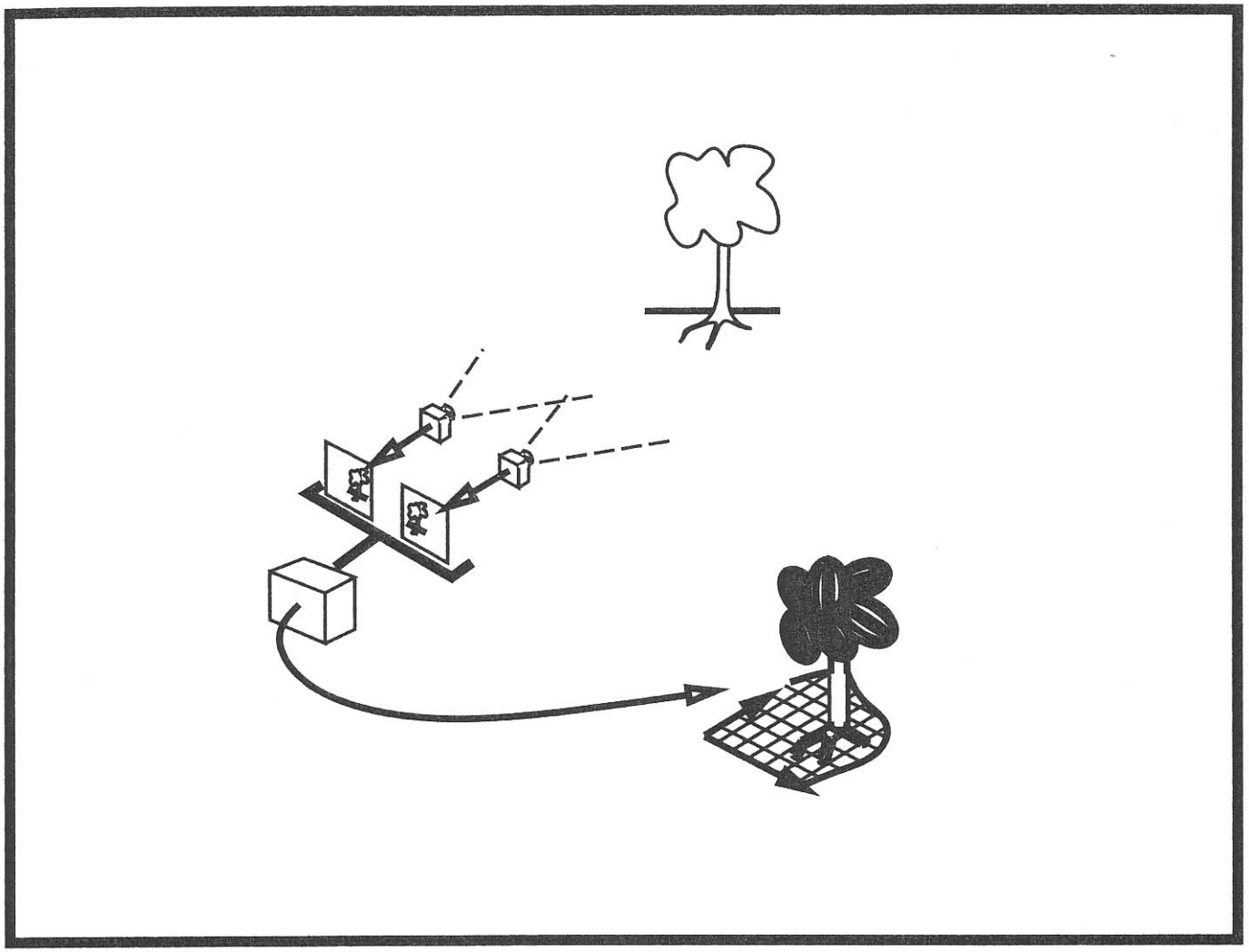
Basket Ball Movie



The evolving views on vision

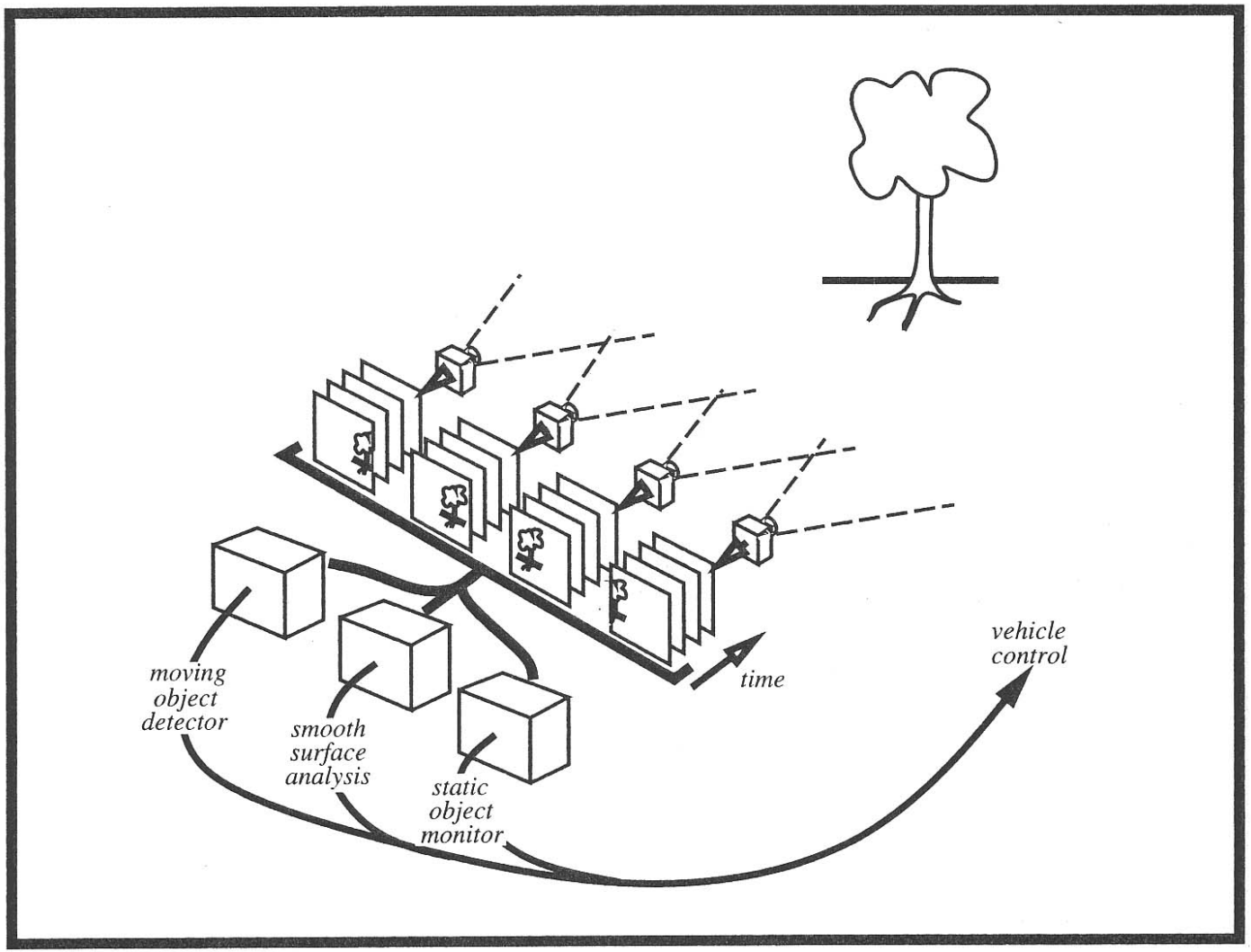
- Build 3D models.
- Use specific vision routines to assist behaviors.
- Use behaviors to assist vision processing.
- Action and perception are one and the same.

Building 3D Models

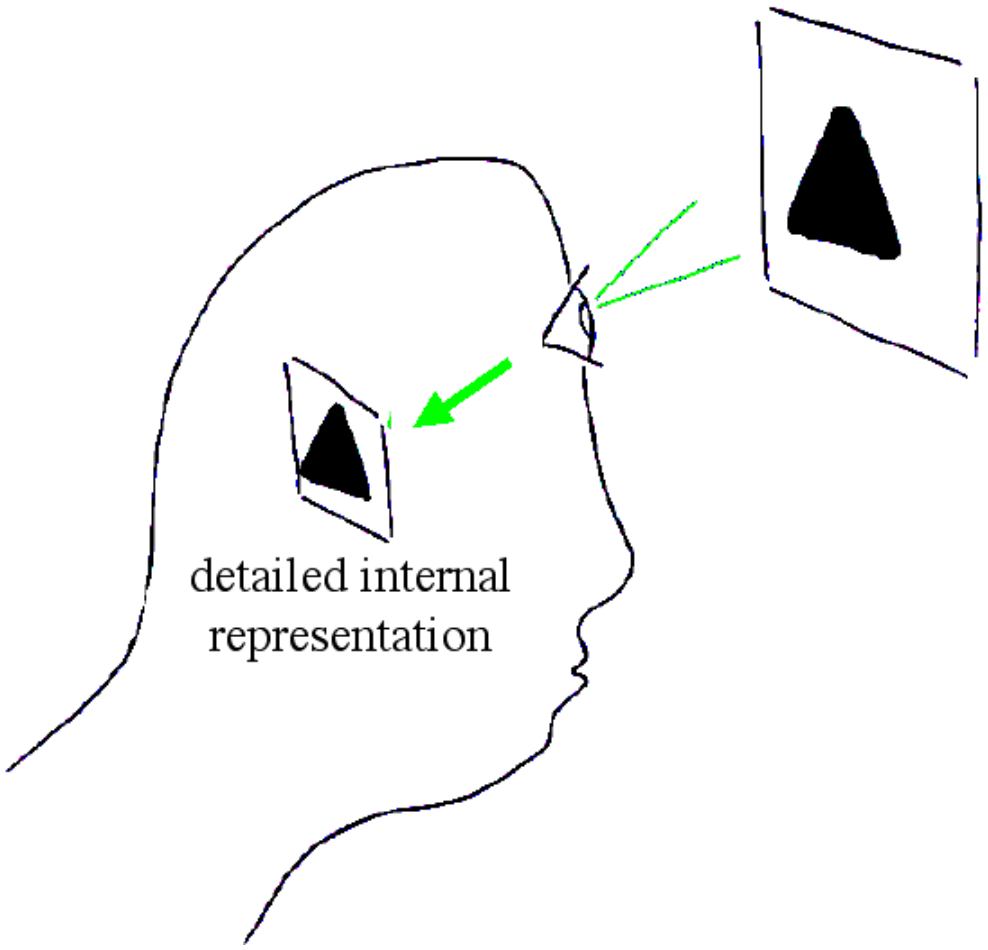


[From Arkin (1998)]

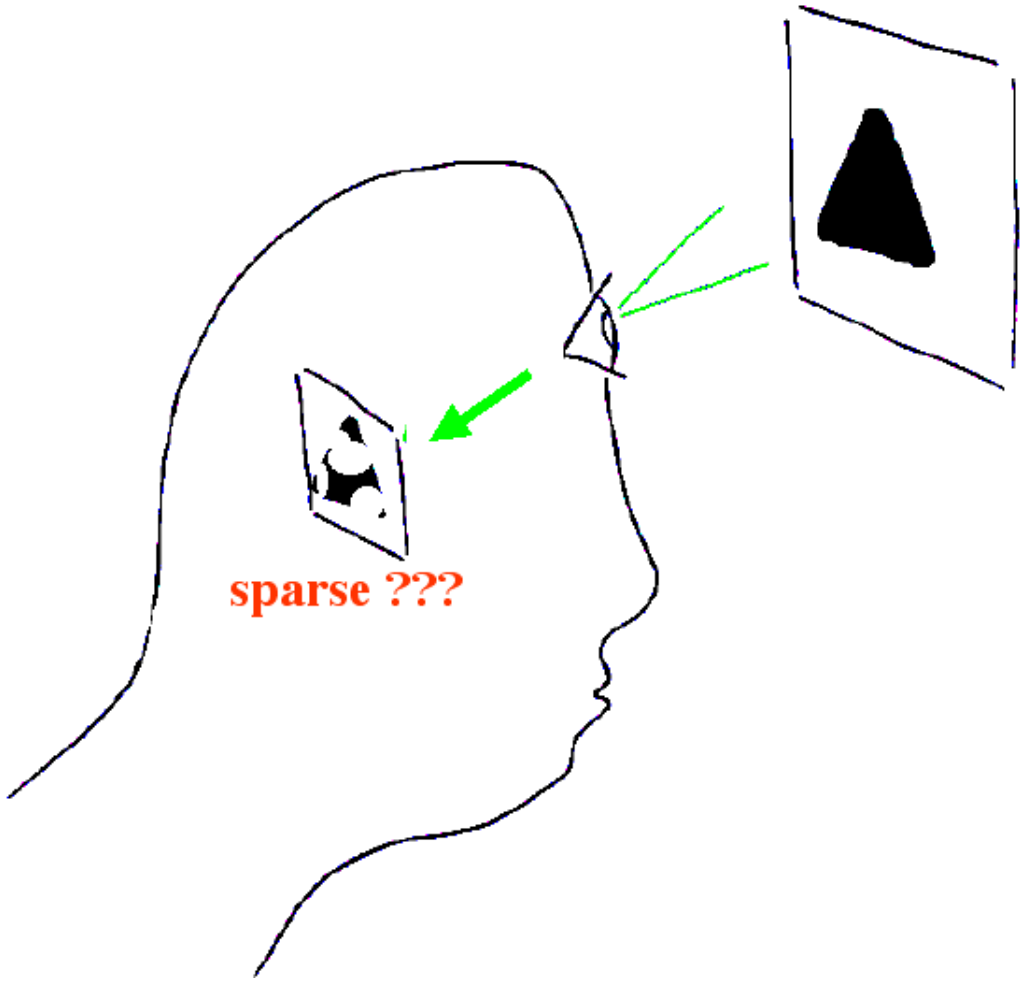
Using specific vision routines to assist behaviors



[From Arkin (1998)]

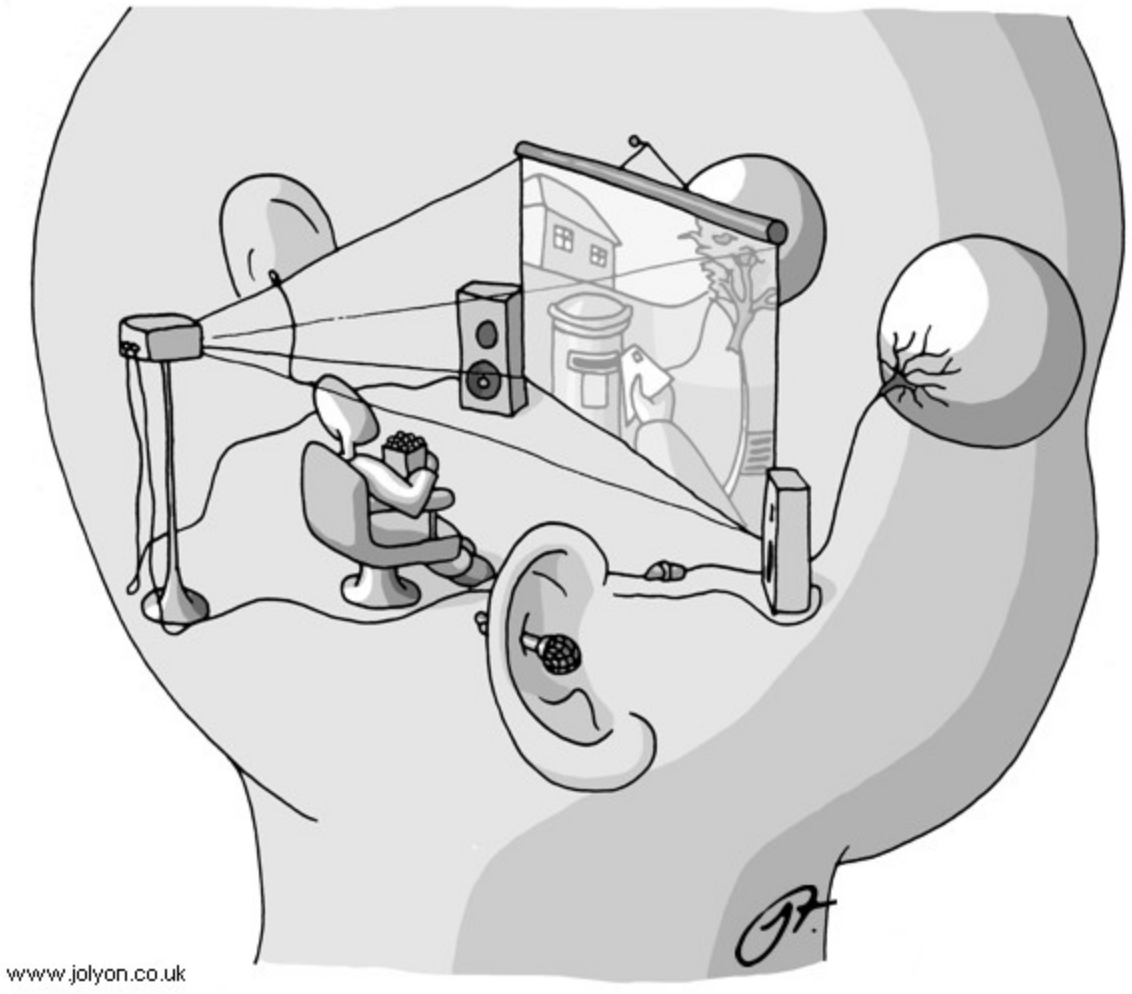


[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]



[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Cartesian Theatre

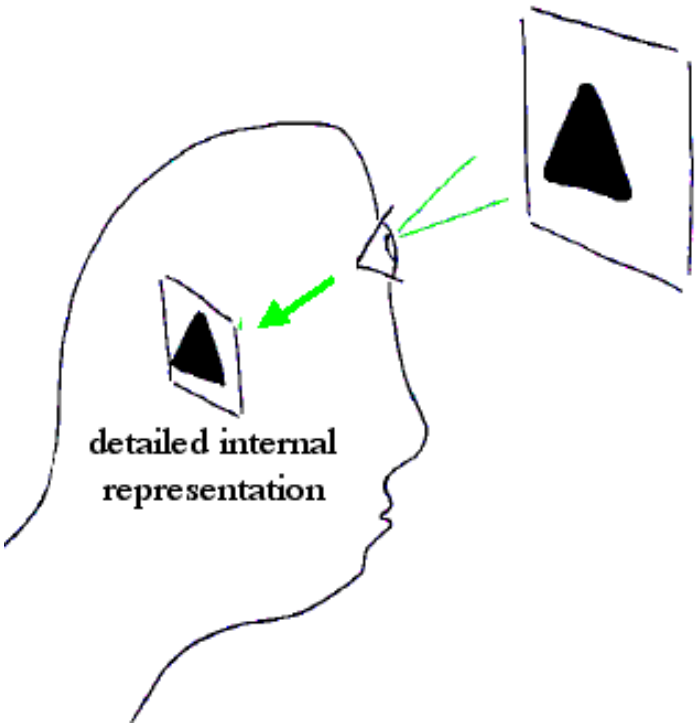


[http://www.jolyont.co.uk/illustrations/consciousnessvsi/index.htm]

THE THEORY

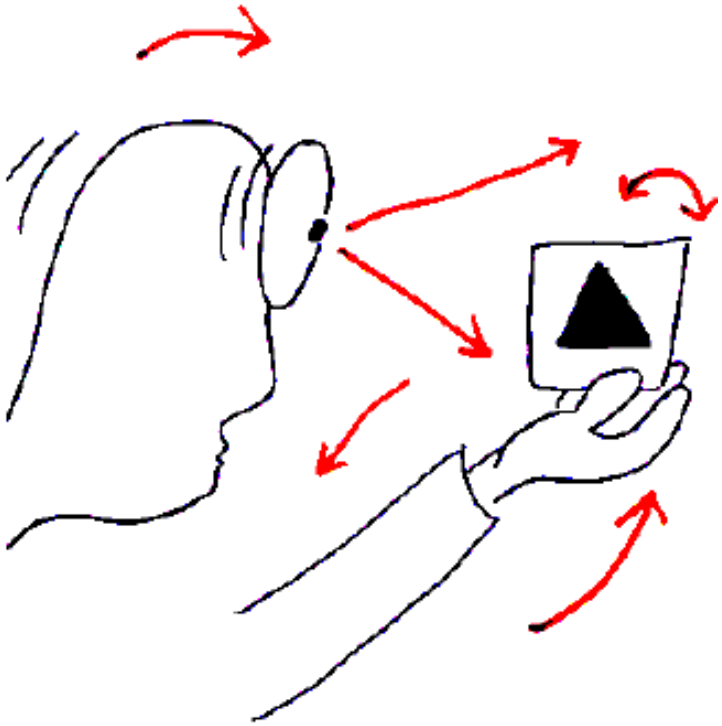
standard view

Seeing is making an internal representation

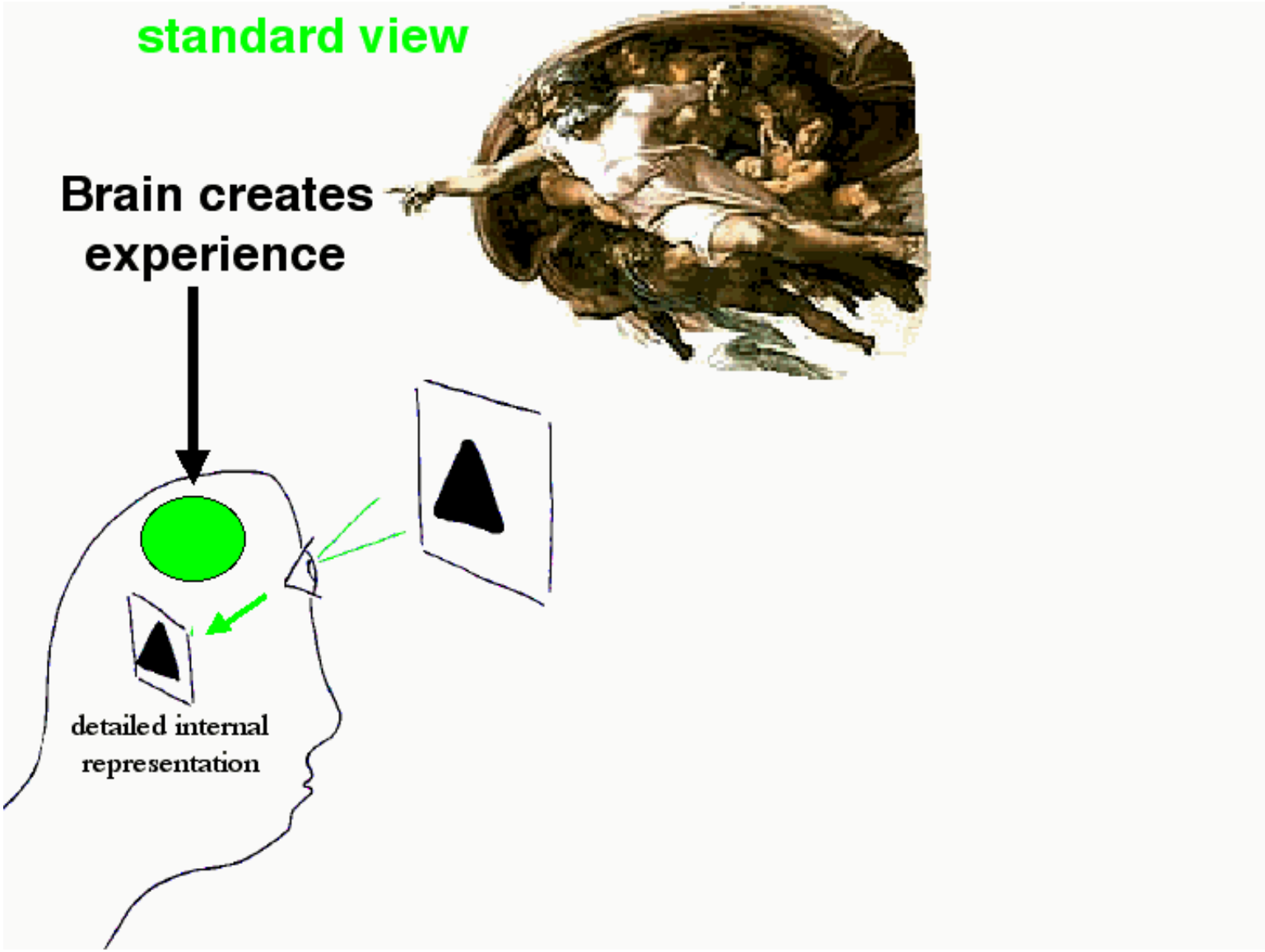


new view

Seeing is knowing about things to do



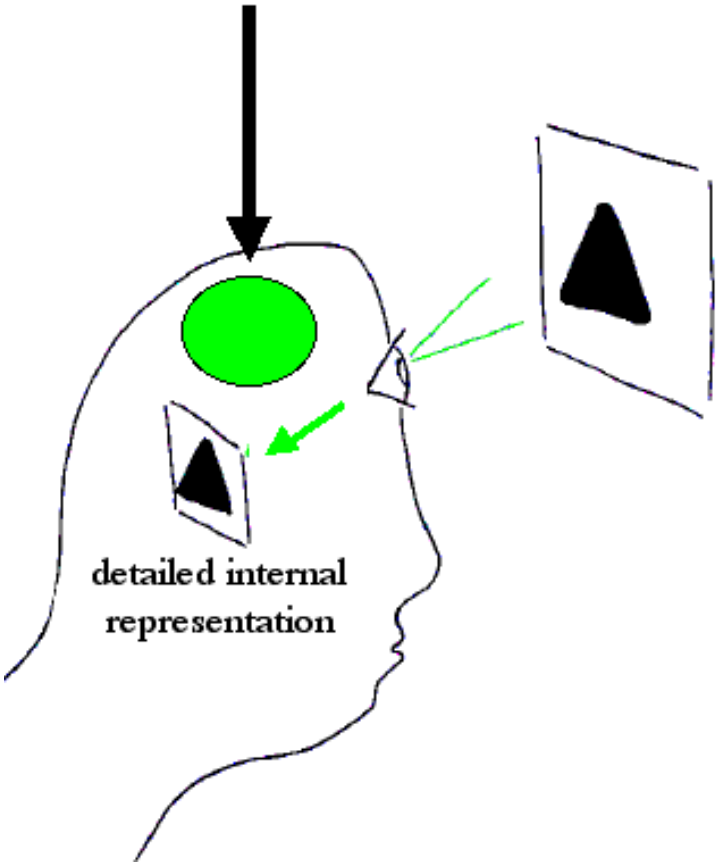
[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]



[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

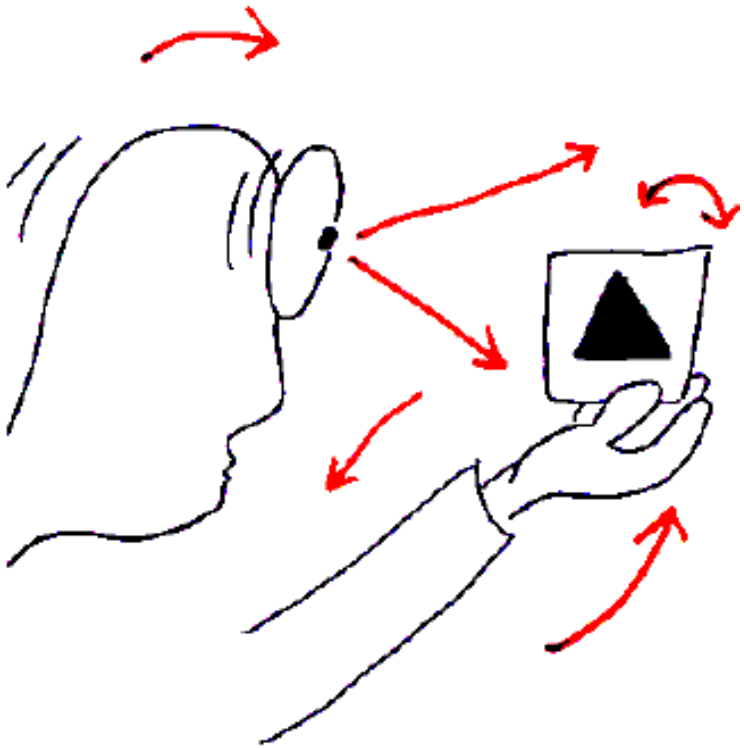
standard view

Brain creates experience



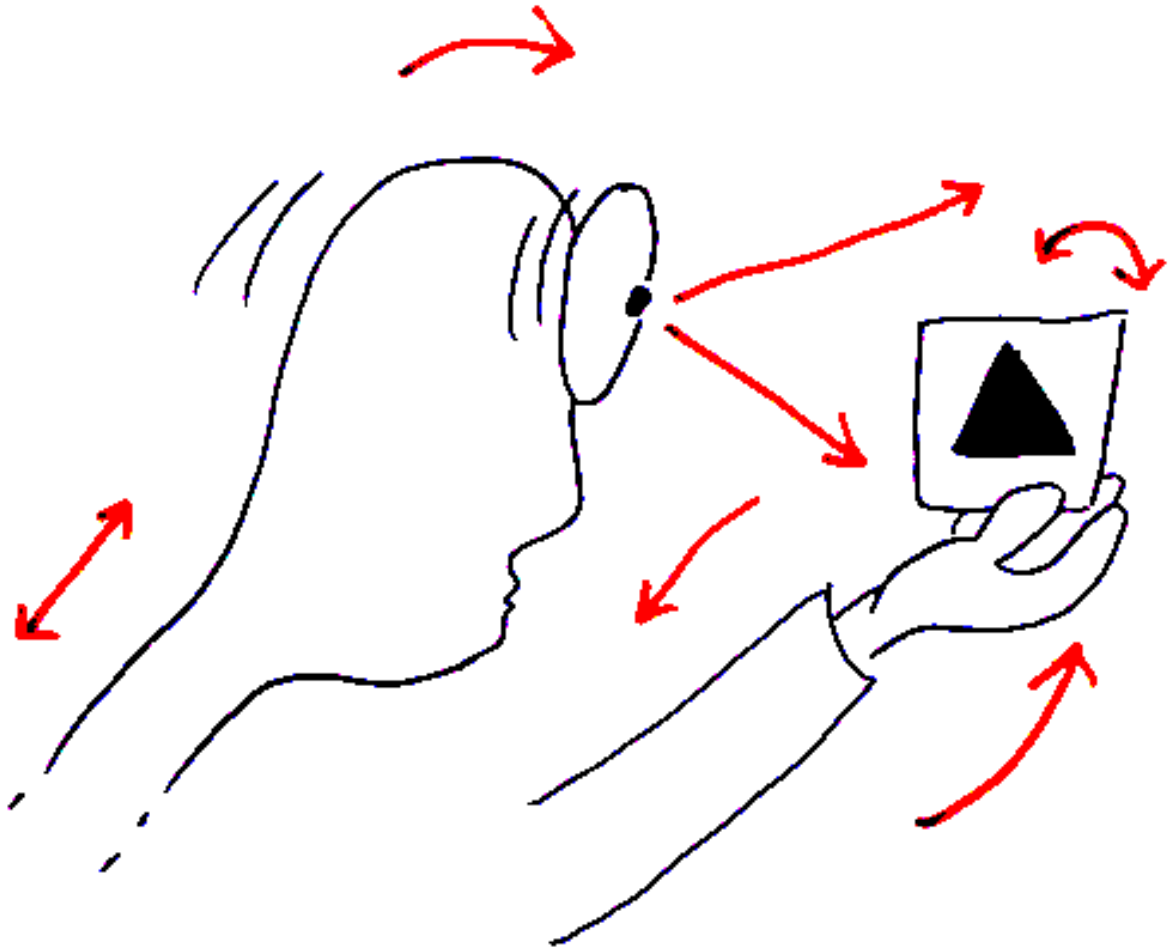
new view

Brain creates actions and has knowledge



[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Seeing is:
Knowing the sensorimotor contingencies



[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Examples of sensorimotor contingencies

	SEEING	HEARING
blink:	big change	no change
move forward:	expanding flow	increasing amplitude
turn sideways:	shifting flow	asynchrony
cover ears:	nothing	big change
cover eyes:	big change	nothing

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

- “We propose that seeing is a way of acting. It is a particular way of exploring the environment.”

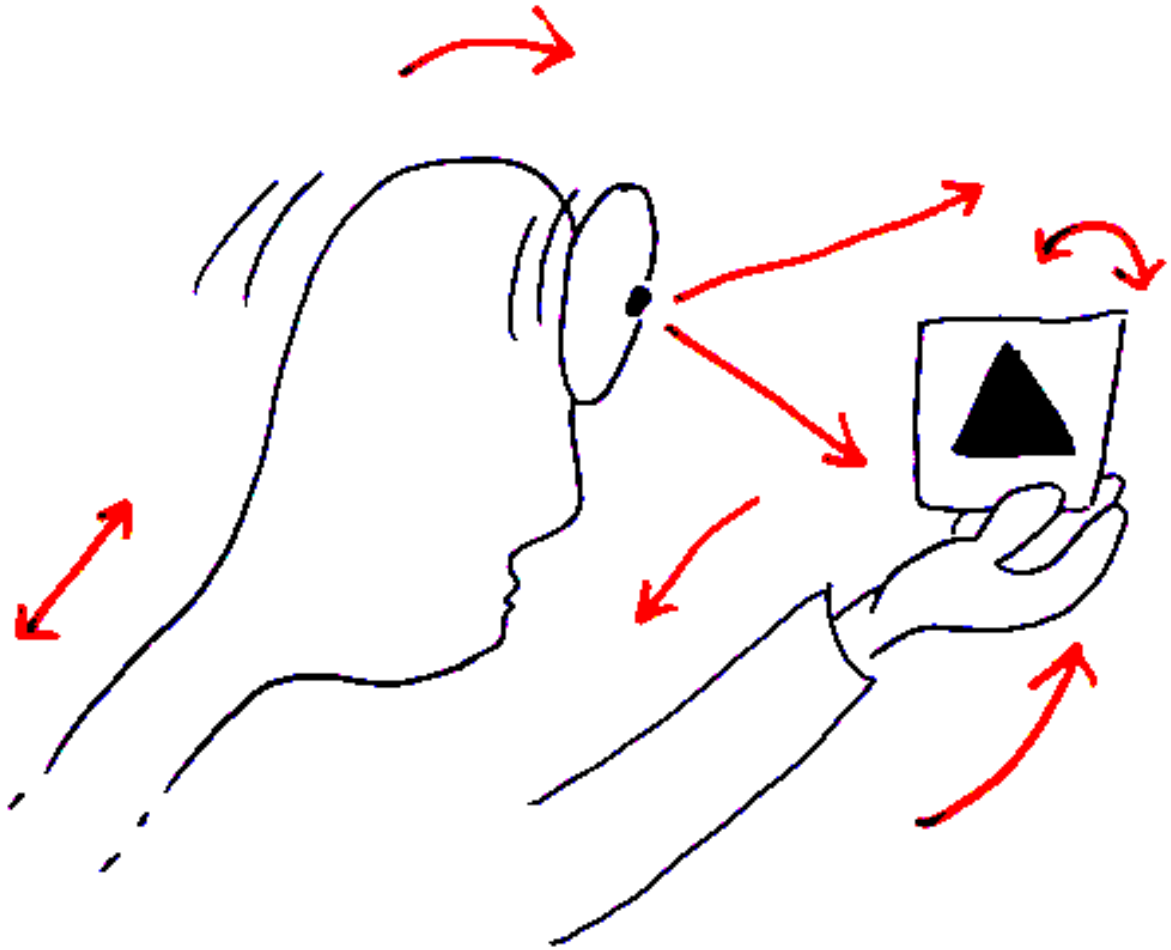
- “The experience of seeing occurs when the organism masters what we call the governing laws of sensorimotor contingency”

[O’Regan and Noë (2001)]

“The idea we wish to suggest here is that the visual quality of shape *is precisely* the set of all potential distortions that the shape undergoes when it is moved relative to us, or when we move relative to it. Although this is an infinite set, the brain can abstract from this set a series of laws, and it is this set of laws which codes shape.”

[O’Regan and Noë (2001)]

Seeing is:
Knowing the sensorimotor contingencies

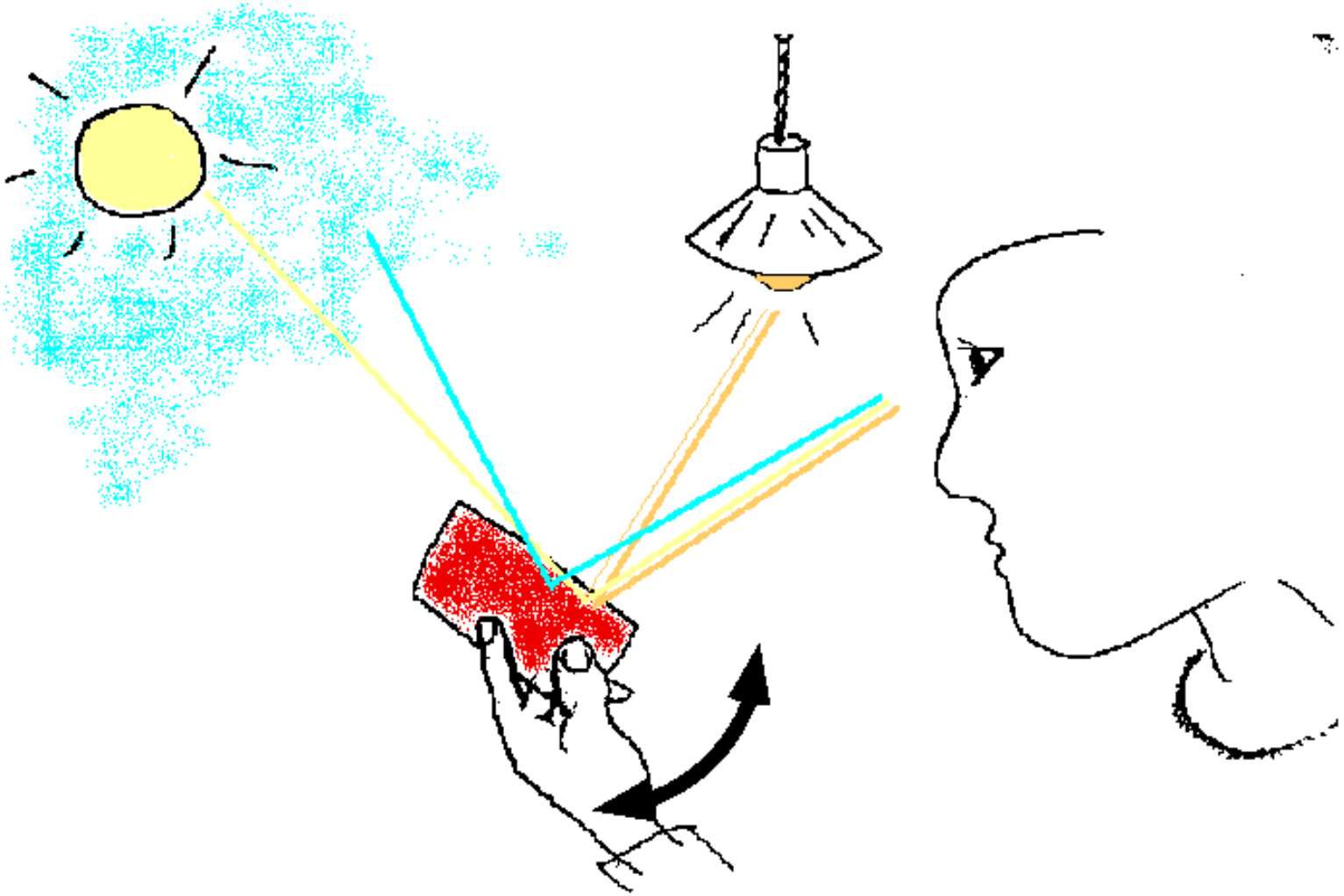


[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Seeing Red

knowing that sensorimotor contingencies typical of red are currently being obeyed.

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

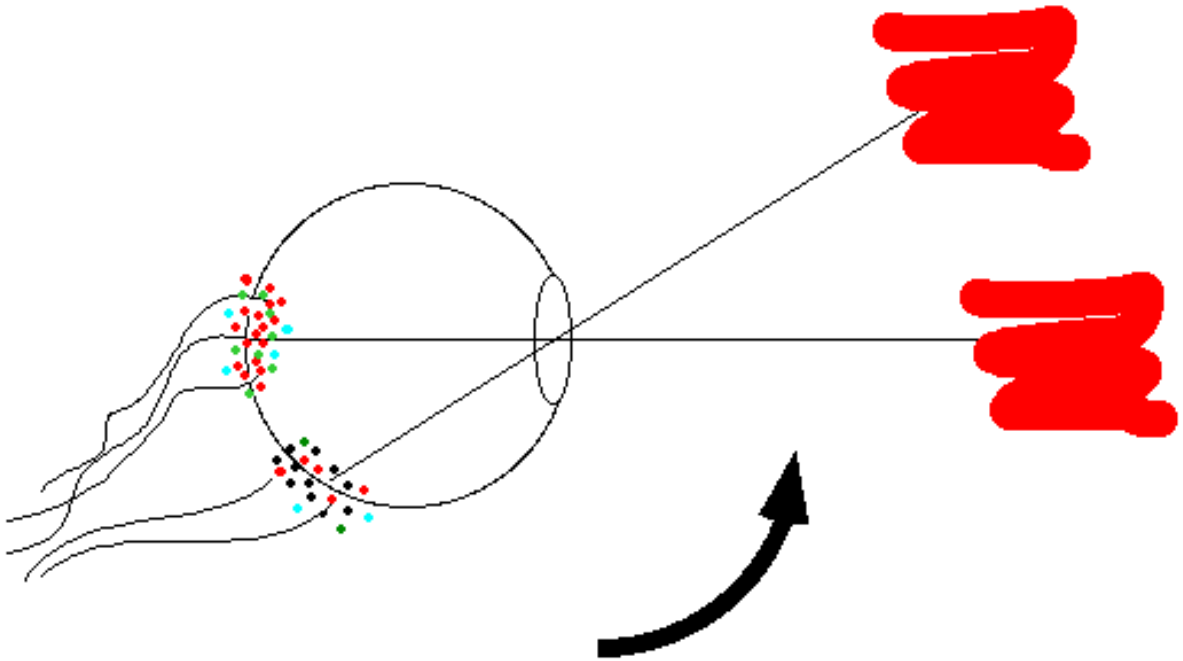


"Red" is the way red things change the light

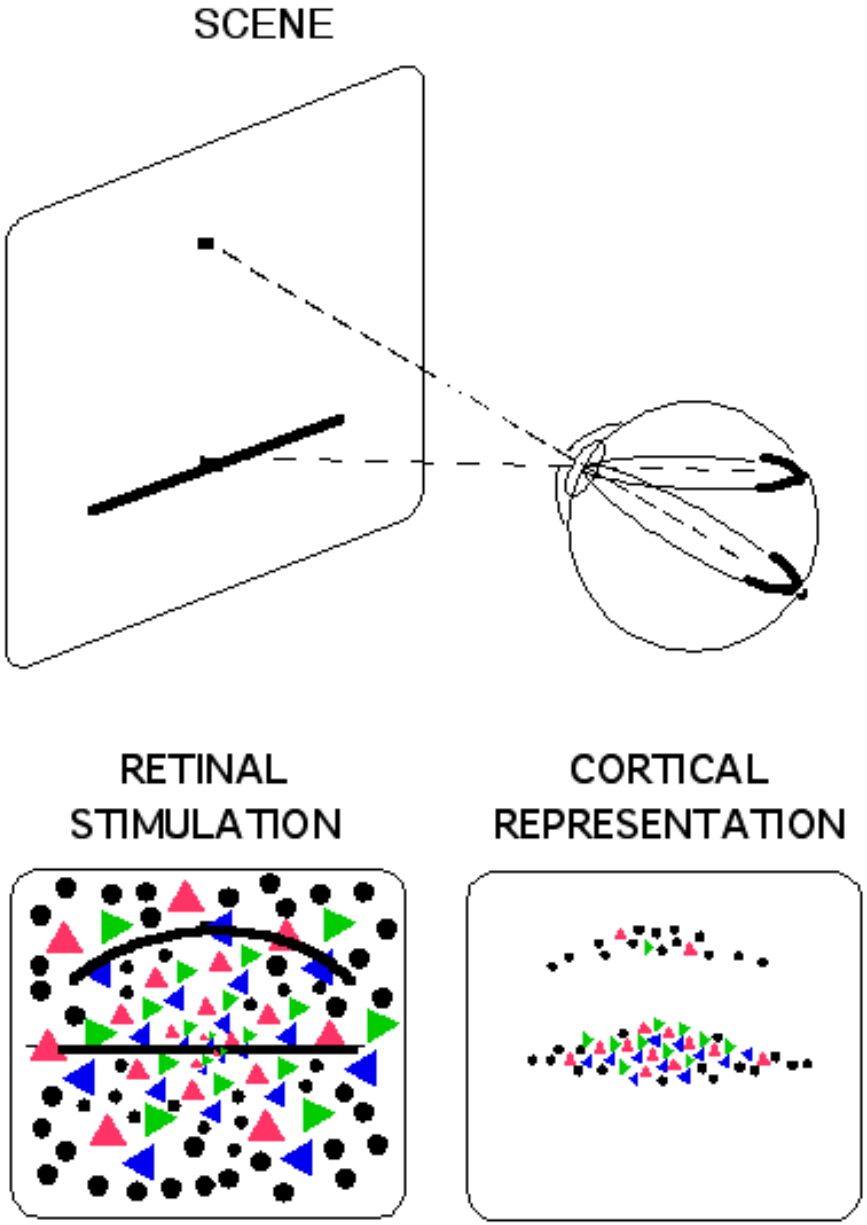
(Broackes, 1992)

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Non-uniformity of color sampling



[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]



[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Qualia

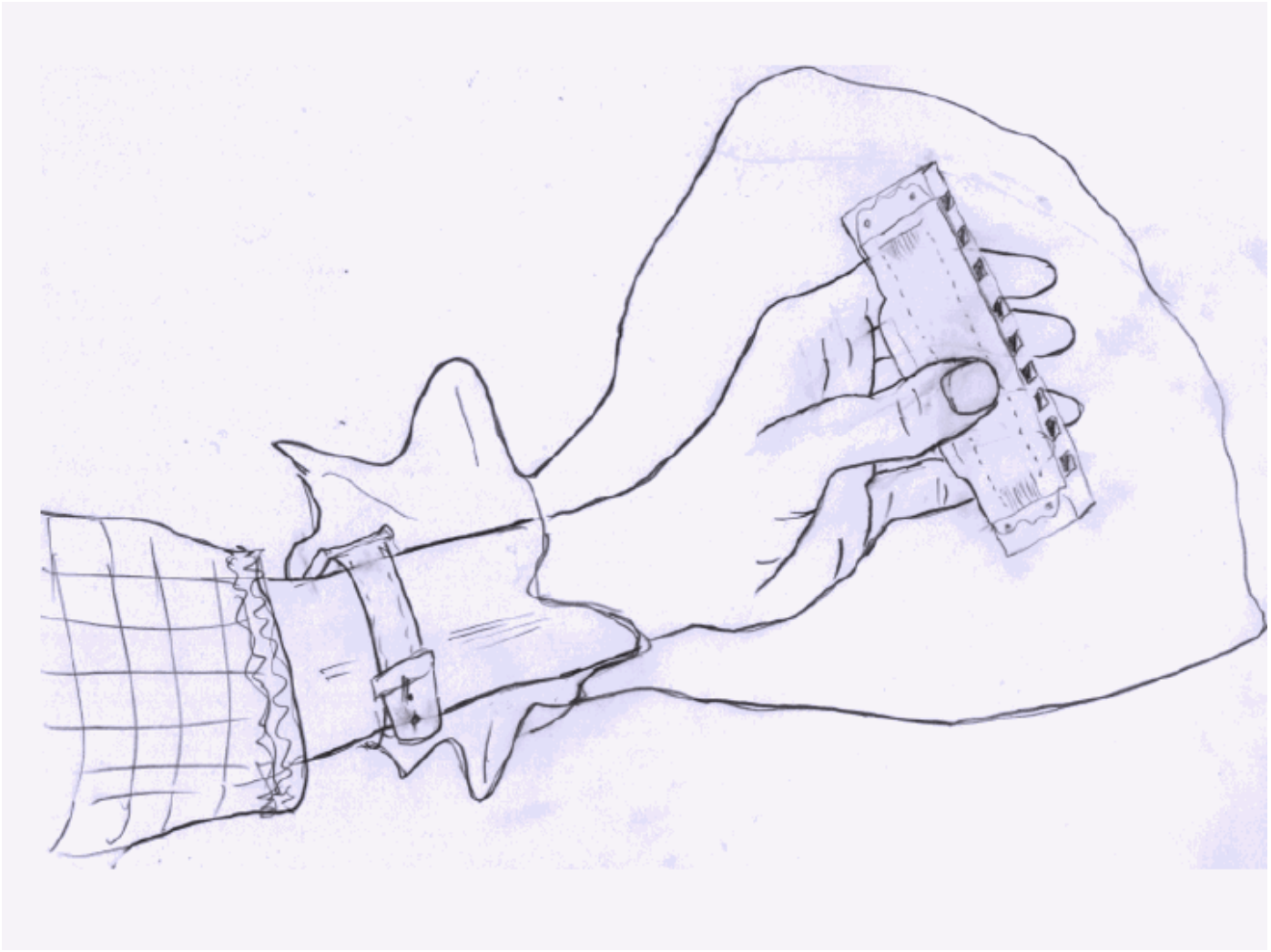
- “Why is the experience of red more like the experience of pink than it is like that of black?”

- “More generally, why is seeing red very different from hearing a sound or smelling a smell?”

[O’Regan and Noë (2001)]

THE END

Analogy to Touch



[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Game of Tactile Recognition

The game of tactile recognition encourages the use of two sense, sight and touch. The game contains 25 wooden shapes, 5 boards and a cloth bag in which to hide the shapes. A variety of exercises are provided including: Feeling the objects in the bag, locating the objects on the board, finding a matching object etc, etc. Similar exercises can be undertaken by replacing the visual and tactile elements with verbal instructions.

[http://www.westons.com/acatalog/info_AOAC1322.html]

Seeing is:

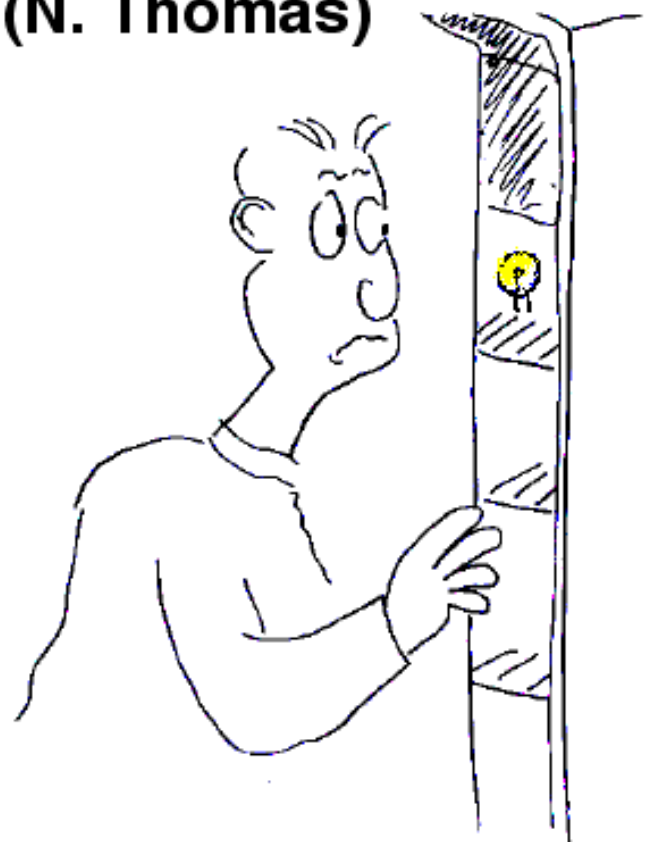
Having access to information through eye movements

- **Problem: Impression of continuousness?**

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Why we think we see everything

- Seeing is having access
- Refrigerator light analogy (N. Thomas)



[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

The illusion of seeing continuously

- **bodiliness**
  - tight link to body motions
- **grabbiness**
  - transients incontrovertibly grab attention

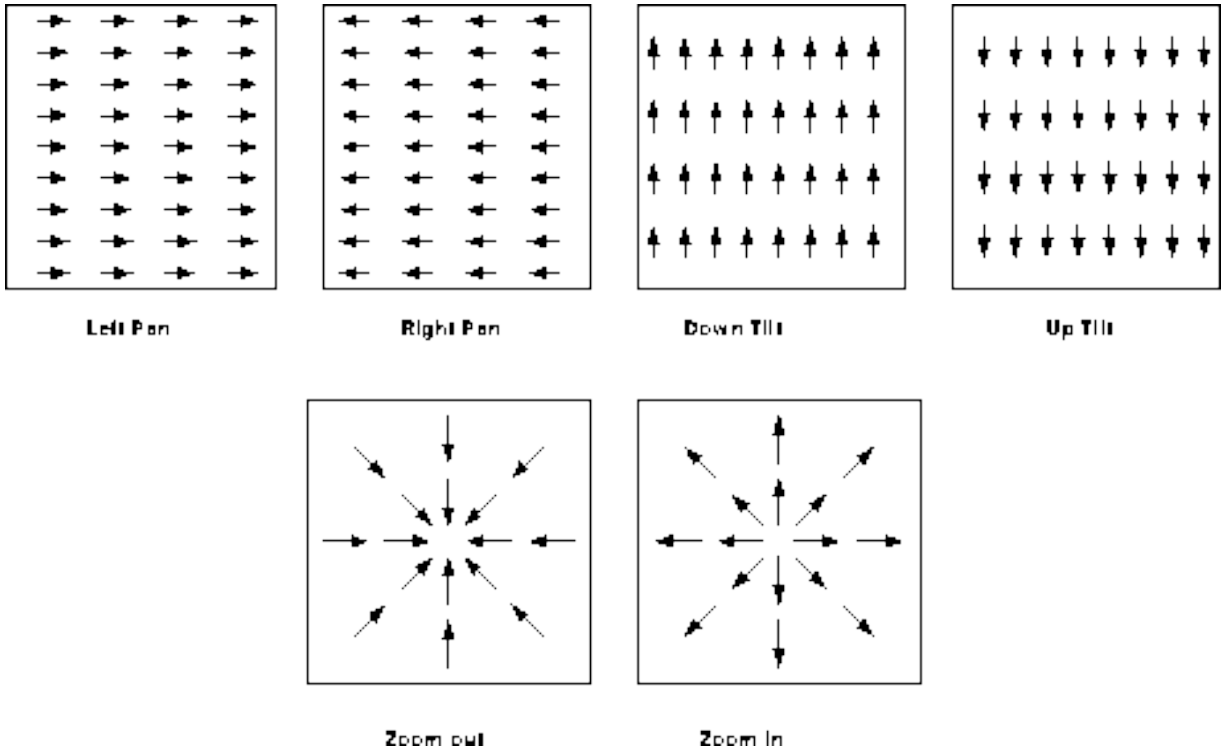
[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Sensorimotor contingencies of SEEING

blink:	big change
move forward:	expanding flow
turn sideways:	shifting flow
cover ears:	nothing
cover eyes:	big change

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Optical Flow



Examples of sensorimotor contingencies

	SEEING	HEARING
blink:	big change	no change
move forward:	expanding flow	increasing amplitude
turn sideways:	shifting flow	asynchrony
cover ears:	nothing	big change
cover eyes:	big change	nothing

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Two Main Types of Sensorimotor Contingencies

- Type I: those fixed by the visual apparatus
- Type II: those fixed by the character of objects. (i.e., particular to the way objects occupy three-dimensional space and present themselves to the eye).

- The animal, or its brain, must be “tuned to” these laws of sensorimotor contingencies. That is, the animal must be *actively exercising* its mastery of these laws.

[O’Regan and Noë (2001)]

“The idea we wish to suggest here is that the visual quality of shape *is precisely* the set of all potential distortions that the shape undergoes when it is moved relative to us, or when we move relative to it. Although this is an infinite set, the brain can abstract from this set a series of laws, and it is this set of laws which codes shape.”

[O’Regan and Noë (2001)]

Some old problem appear as non problems

- Filling-in of the blind spot
- Visual stability despite eye movements

Seeing without eye movements

- “it is impossible to count more than four dots that are fixed with respect to the retina: a rather surprising fact.”

- Chinese characters experiment (Nazir & O’Regan 1990)

[O’Regan and Noë (2001)]

“ … seeing is not directly related to having a retinal image, but to being able to manipulate the retinal image.“

[O’Regan and Noë (2001)]

- “We therefore suggest that a crucial fact about vision is that visual exploration obeys certain laws of sensorimotor contingency. These laws are determined by the fact that the exploration is being done by the visual apparatus.”

[O’Regan and Noë (2001)]

- “… the experience of perception derives from the *potential* to obtain changes in sensation, not from the sensations themselves.”

- “what is important is the sensorimotor invariance structure of the changes in sensation, not the sensation itself.”

- “The present theory shows that in themselves, sensations are situated nowhere.”

[O’Regan and Noë (2001)]

On Sensory Substitution

"An immediate consequence of the notion that experience derives not from sensation itself, but from the rules that govern action-related changes in sensory input, is the idea that visual experience should be obtainable via channels other than vision, provided that the brain extracts the same invariants from the structure of the sensori-motor contingencies."

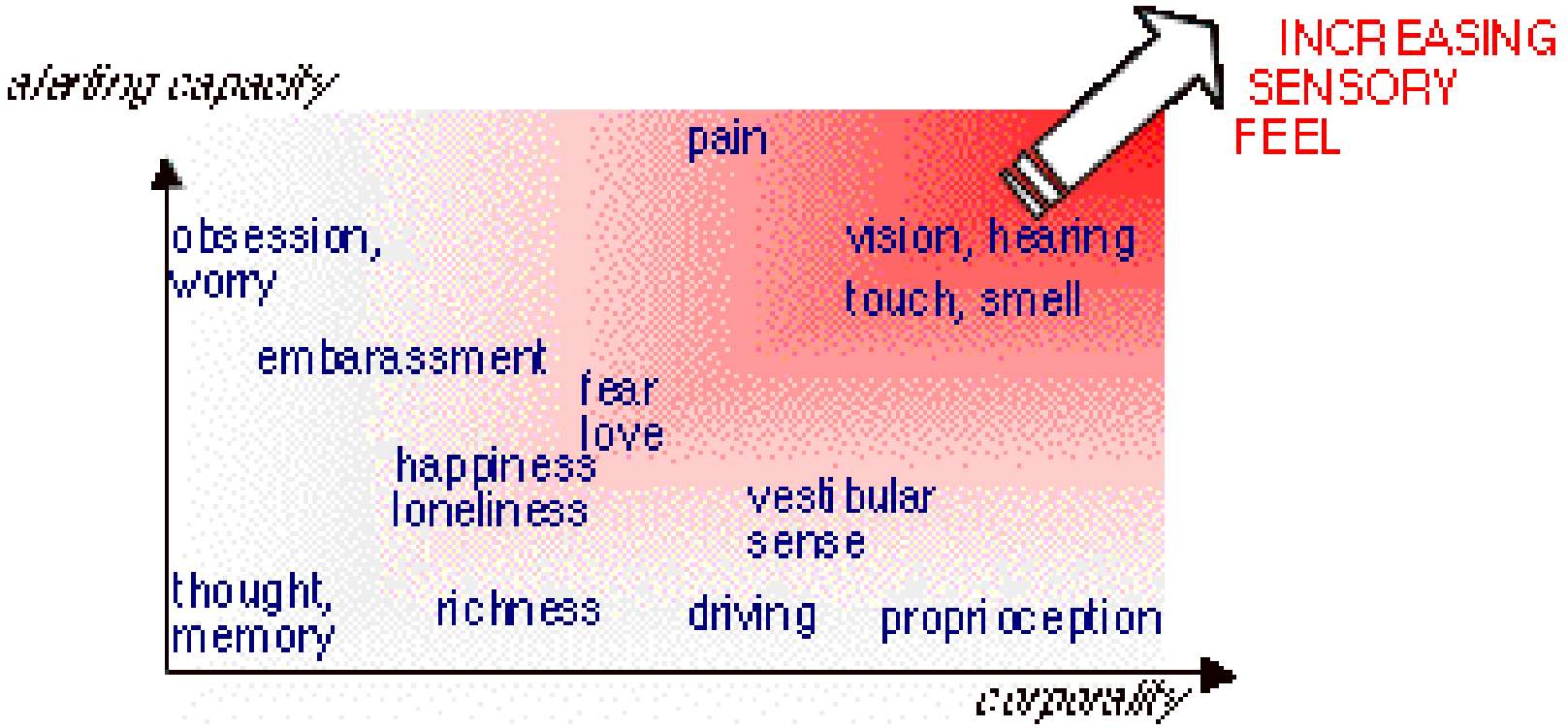
[O'Regan and Noë (2001)]

Memory and Vision

- **Immediate access to information**
  - **memory: in brain**
  - **vision: in world**
- **Difference in quality**
  - **bodiliness/grabbiness**

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

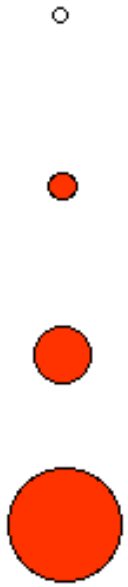
A sensory phenomenality plot



[http://nivea.psycho.univ-paris5.fr/CONS+COG/CC_OREGAN.htm]

	bodiliness	grabbiness
memory	--	--
wealthiness	+	-
driving	++	-
seeing	+++	+++

"raw feel"



[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Memory

bodiliness	grabbiness
--	--

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Seeing

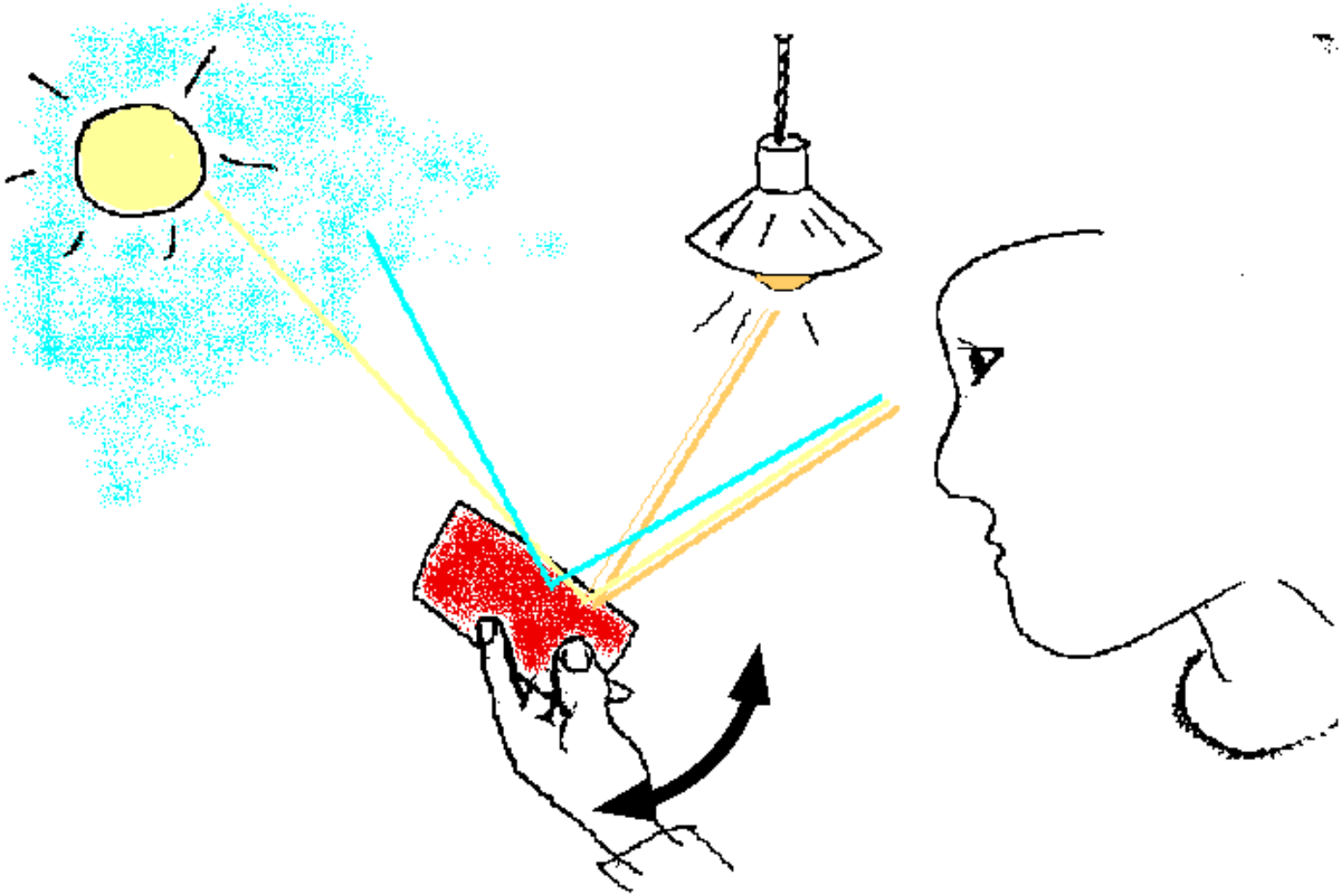
bodiliness	grabbiness
+++	+++

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Seeing Red

knowing that sensorimotor contingencies typical of red are currently being obeyed.

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

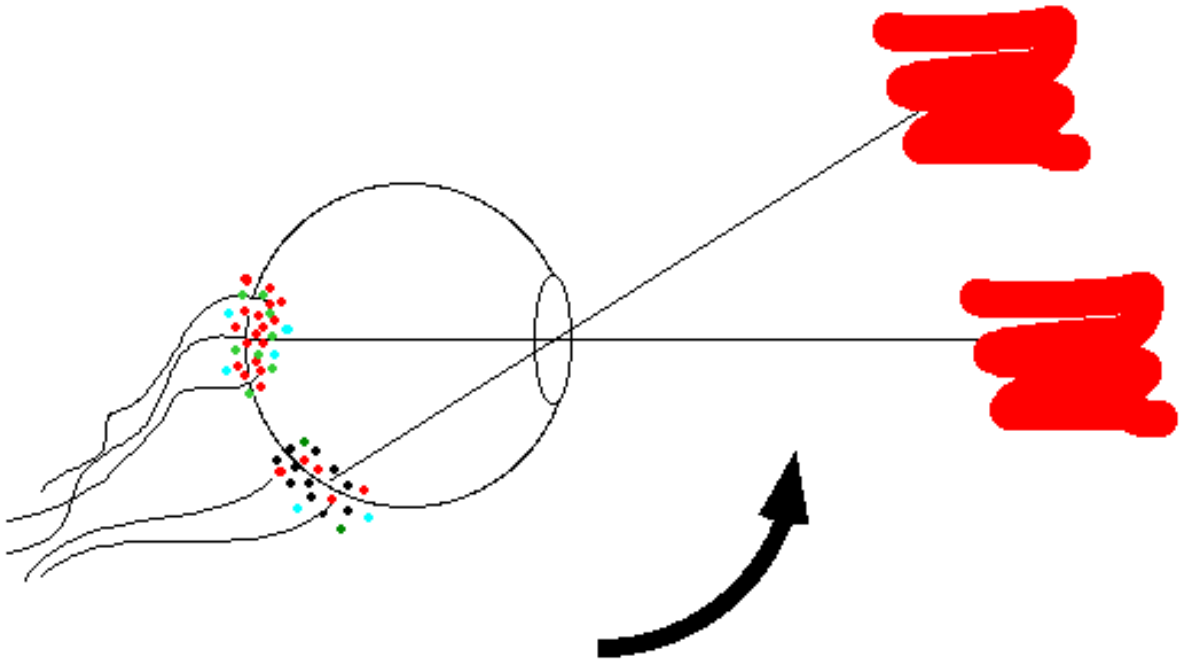


"Red" is the way red things change the light

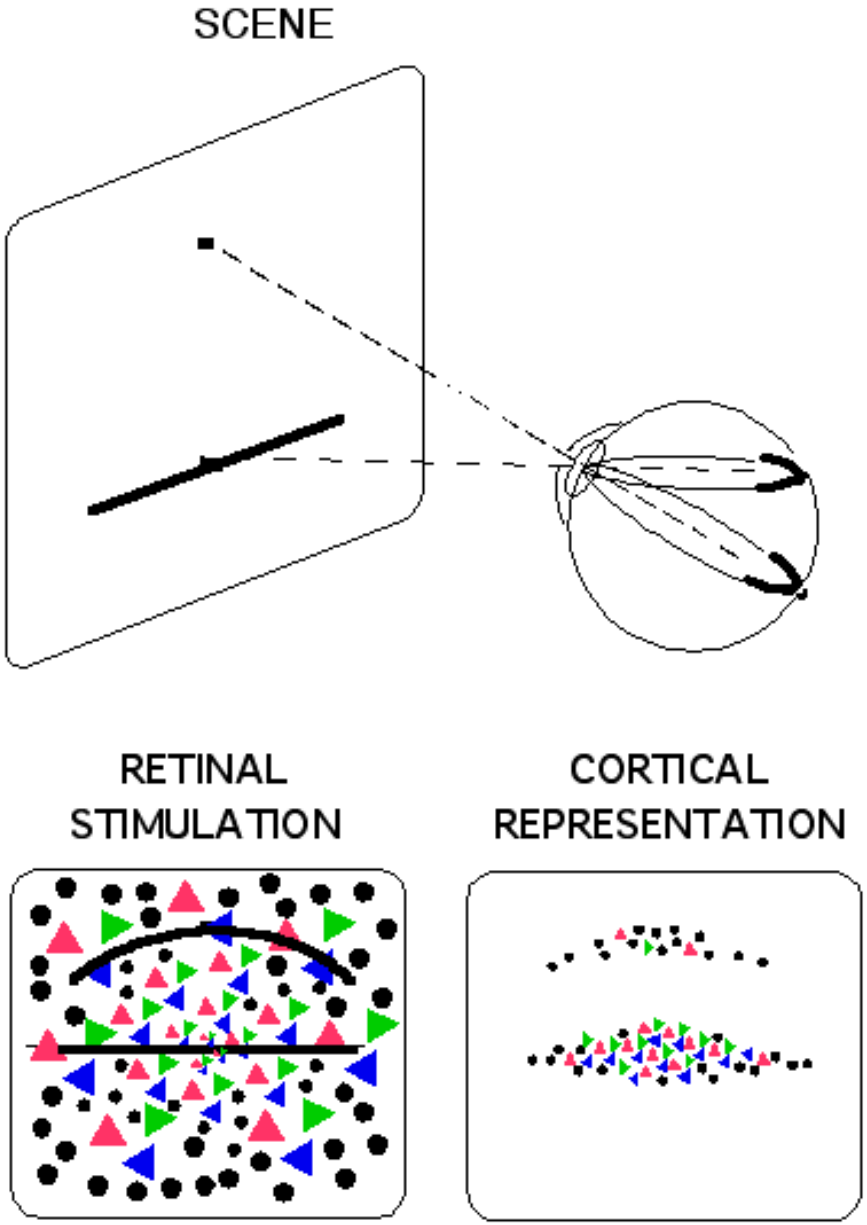
(Broackes, 1992)

[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Non-uniformity of color sampling



[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]



[http://nivea.psycho.univ-paris5.fr/ASSChtml/ASSC.html]

Half-Split Colored Spectacles

[Bompas and O’Regan(2005)]

Qualia

- “Why is the experience of red more like the experience of pink than it is like that of black?”

- “More generally, why is seeing red very different from hearing a sound or smelling a smell?”

[O’Regan and Noë (2001)]

THE END

Reading Discussion

“How does the conversion of analog to digital image take place?”

Reading Discussion

“How does the conversion of analog to digital image take place?”

“Do the gray values change in any way with newer cameras that are able to take clearer pictures? I know the amount of pixels increases.”

Reading Discussion

“I thought that the object level computation in an image posing a catch-22 situation was interesting. I would like to learn more about the criteria of how researchers clump points into objects based on their characteristics.”

Reading Discussion

“How relevant is the philosophical aspect of seeing, or the “visual experience”? For example, the paper talks about “qualia,” which are “intrinsic” properties of the something, as opposed to representational or functional features. The paper makes a good point that they are hard to quantify, but are they completely useless? Is there no use for the subjectivity of one’s experience with some event?”