Dynamics and Modeling in Cognitive Science - I

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Outline

- General introduction to Cognitive Science
- Problem Domains
  - Perception
  - Attention
  - Consciousness
  - Language
  - Decision Making
- Different types of models
  - Symbolic
  - Connectionist/Dynamical

What is cognitive science?

- Cognitive science is the science of mind and behavior
- Cognitive science is about how the mind processes information.

Interdisciplinary Approach

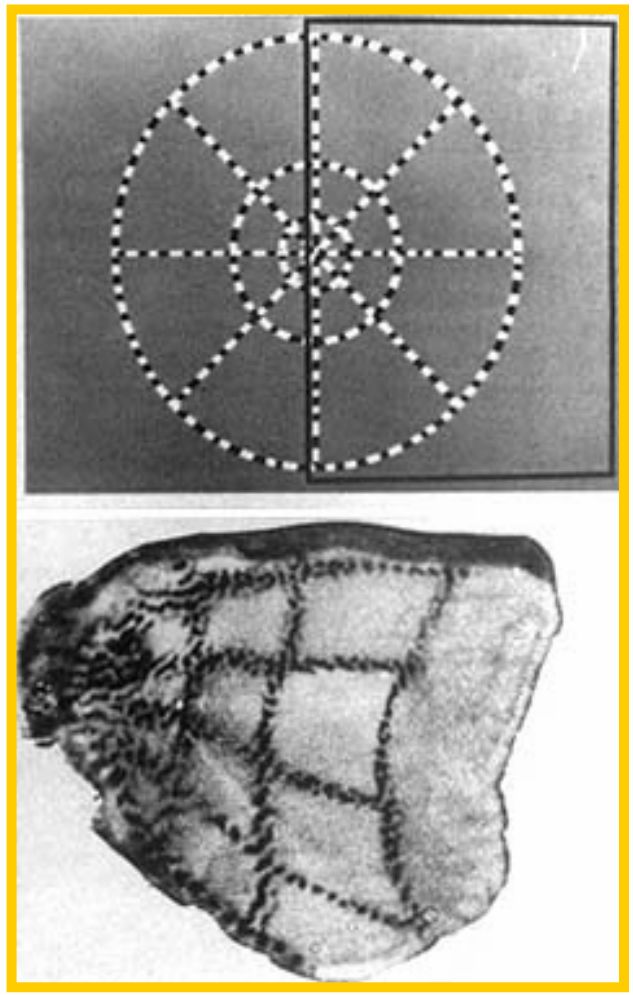
- Cognitive Psychology, developmental psychology …
- Linguistics – syntax, semantics, phonology …
- Neuroscience – brain structures, localization …
- Computer science – AI, computer models …
- Philosophy – theoretical foundations …
- Anthropology – culture and cognition

Information processing domains

- Perception
  - acquiring real-time information about the surrounding environment.
- Language use
  - making use of information about syntax, semantics and phonology.
- Reasoning
  - combining different sources of information, deriving new information, testing consistency of information, etc.
- Action
  - making use of information in action planning and guidance.
- Memory
  - storing and retrieving information

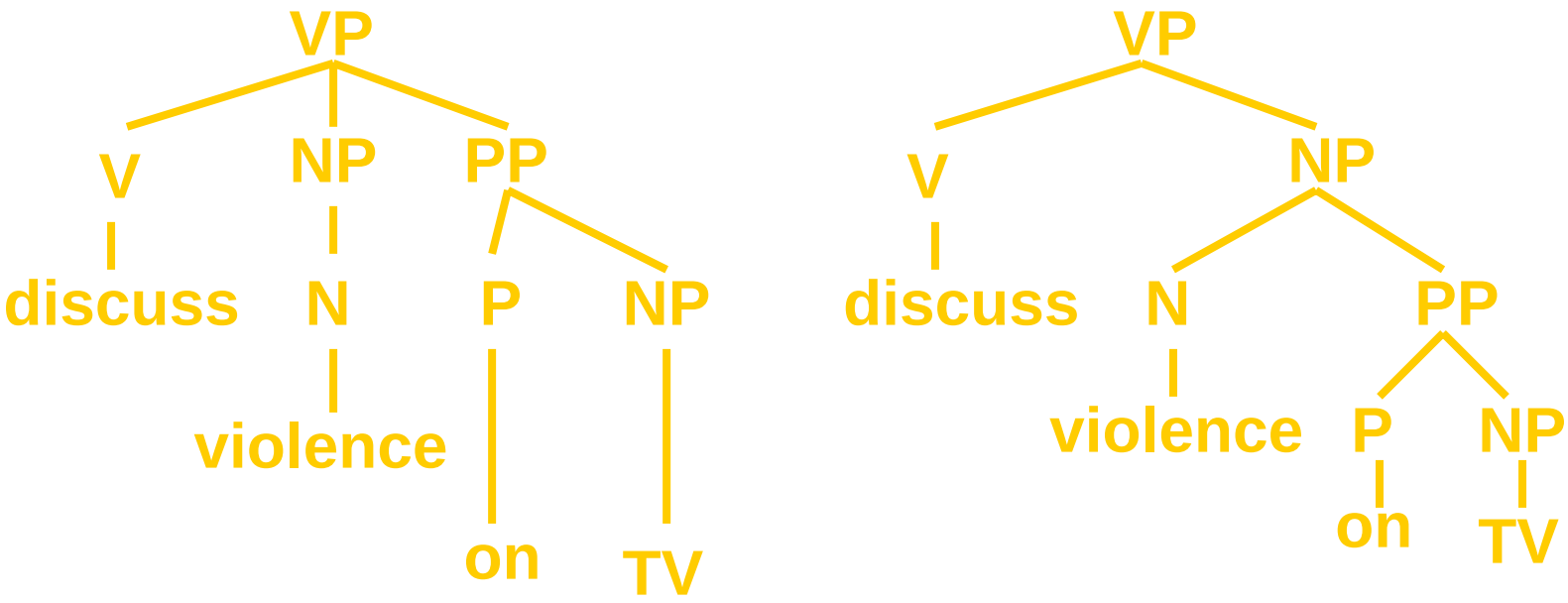
Computation and Representation

- Rule based manipulation of symbols
- Thinking that P = activating a set of symbols in the brain which mean P.



Representations explain lots of things

- Example: Syntactic Disambiguation
  - "We shall discuss violence on TV."
  - Two interpretations :



Computer Models

- **Computer models** can be built to test theories of mental processes.
- There are **different levels of analysis** for a complex information processing system.

Three Levels of Description

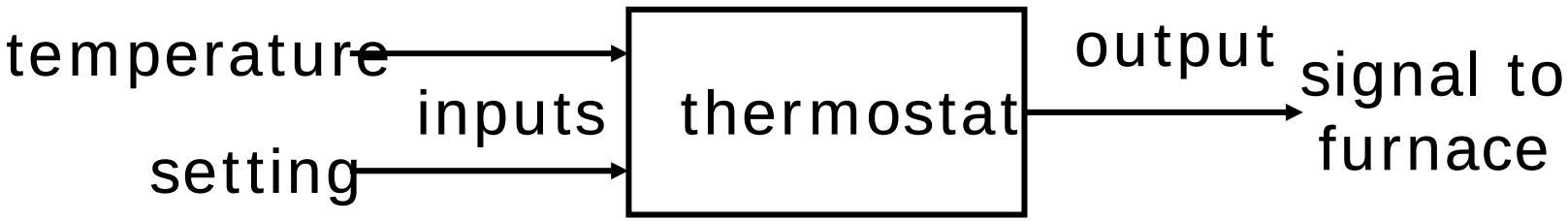
- A complete understanding of a computational system has to involve three (kinds of) levels :
- Computational theory
  - What is computed and why.
  - What the system is capable of doing.
- Representation and algorithm (software)
  - What program is used.
  - What are the symbols and how are they processed.
- Hardware
  - Where in the brain?
  - What kind of neurons and how are they connected?

Marr (1982)

An Example: The Thermostat

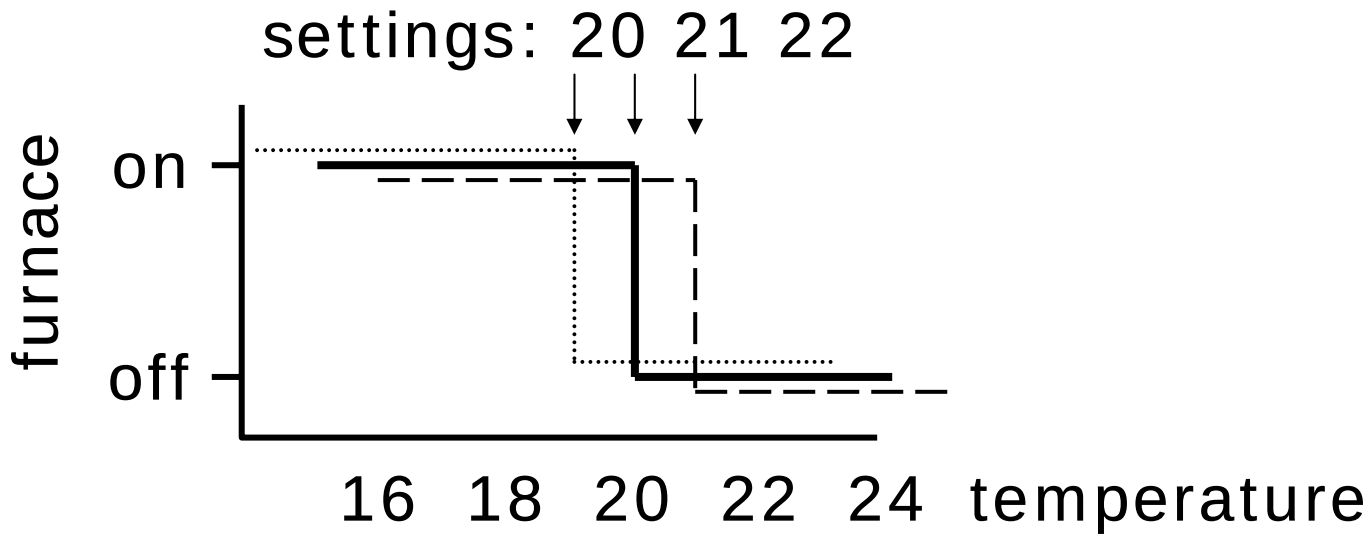
(Palmer 1999)

- The computational level



An Example: The Thermostat

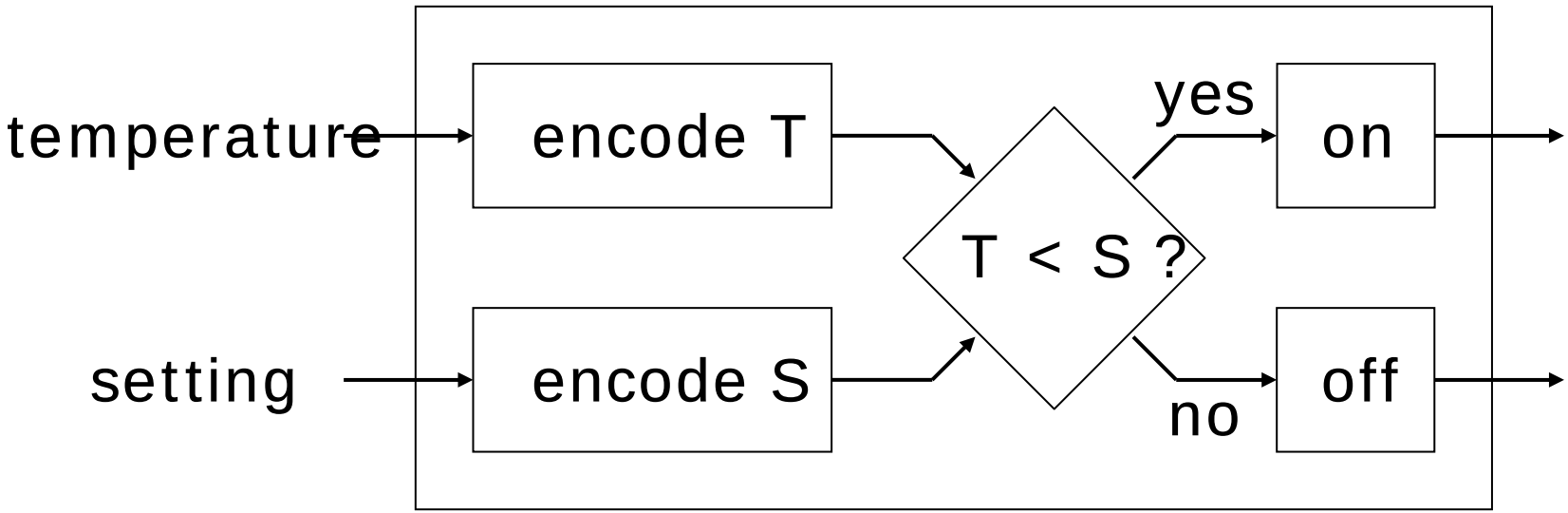
- The computational level (cont'd)



$$O(T, S) = \begin{cases} 1 \text{ iff } T < S \\ 0 \text{ iff } T >= S \end{cases}$$

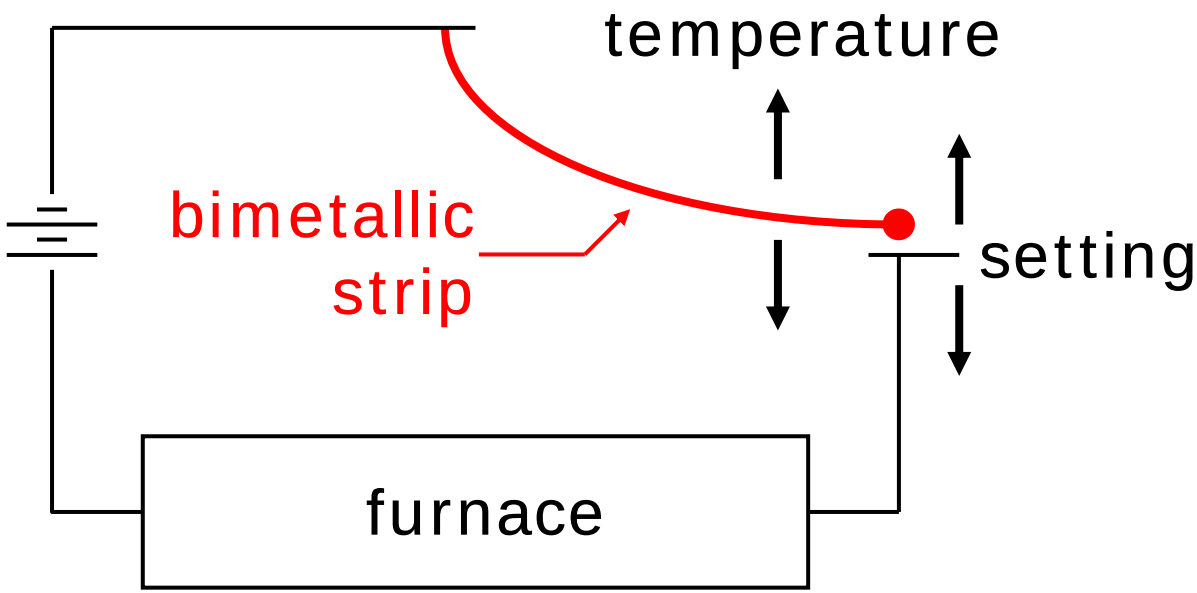
An Example: The Thermostat

- The algorithmic level



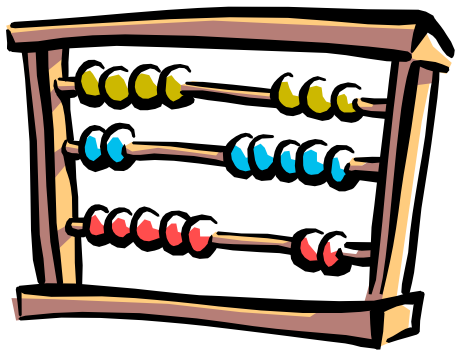
An Example: The Thermostat

- The implementation level



Two points

- The same task can be performed with different algorithms.
  - Two different systems can do the same task in very different ways.
- The same algorithm can be implemented with different hardware.

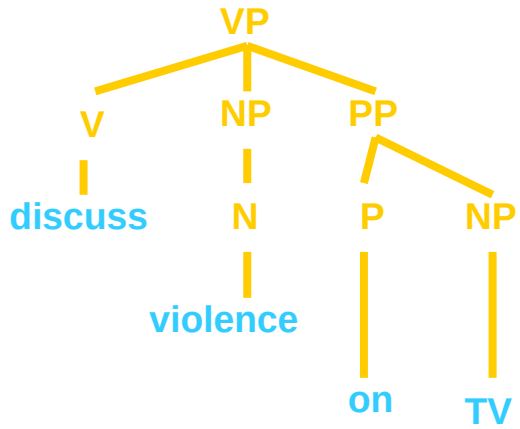


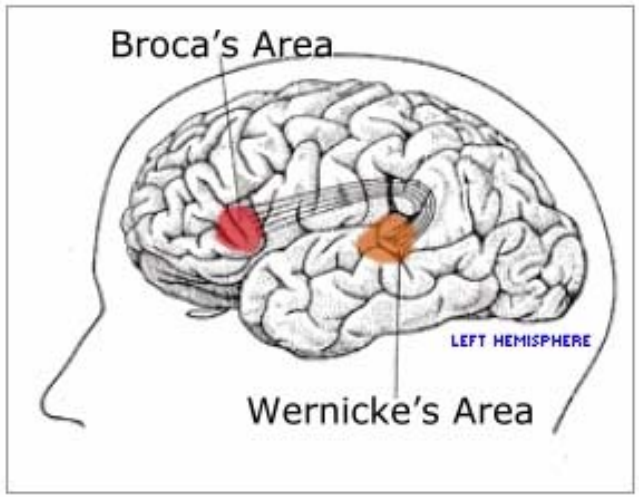
How to study cognitive science

- A computational theory of X should explain X at three levels.
  - What is computed? Visual motion
  - How? Correlate changes in luminance at different places.
  - Hardware? Comparator circuits
    http://www.psypress.co.uk/mather/resources/swf/Demo11_1.swf

Application: linguistic understanding

- **Task**
  - Identify syntax and meaning corresponding to speech sounds.
- **Algorithm**
  - What kind of computation and mental representations?
- **Implementation**
  - Which part of the brain?





A slightly different view IP

- Informational Description
- Recursive Decomposition
- Representations and Processes

Palmer & Kimchi

Visual Perception

goals of field of vision

- *understand* how animals represent and process information carried by light, by
  - measuring and modeling visual performance in humans and other animals
  - finding ways to build artificial visual systems
  - characterizing neural mechanisms underlying vision

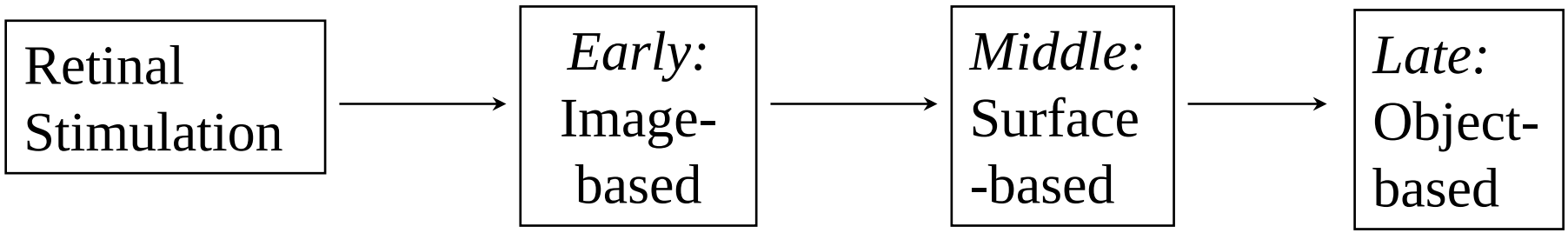
Human Vision

- as a first approximation, rods and cones (sensory cells in the retina) represent image as large 2D array of light intensities
  - about 126 million sensory cells!
- this image representation is processed by brain enabling complex cognitive functions
  - recognize a familiar face or scene
  - disambiguate overlapping objects
  - read sloppy handwriting
- how does the brain do all of this?
- how might perceptual processing be partitioned into subtasks?

Visual Routines

- possible tasks:
  - extraction of contour (e.g. sharp light intensity changes in the image)
  - extraction of motion
  - identification of object parts
- still unclear: how are these integrated to enable us to extract meaning from what we see?

Perception: Early, Middle, Late Vision



- Early (e.g., edge detection, color, motion, etc)
- Middle (e.g., segmentation, grouping, figure-ground separation, etc)
- Late (e.g., Shape analysis, object recognition, navigation)

Basic Terms

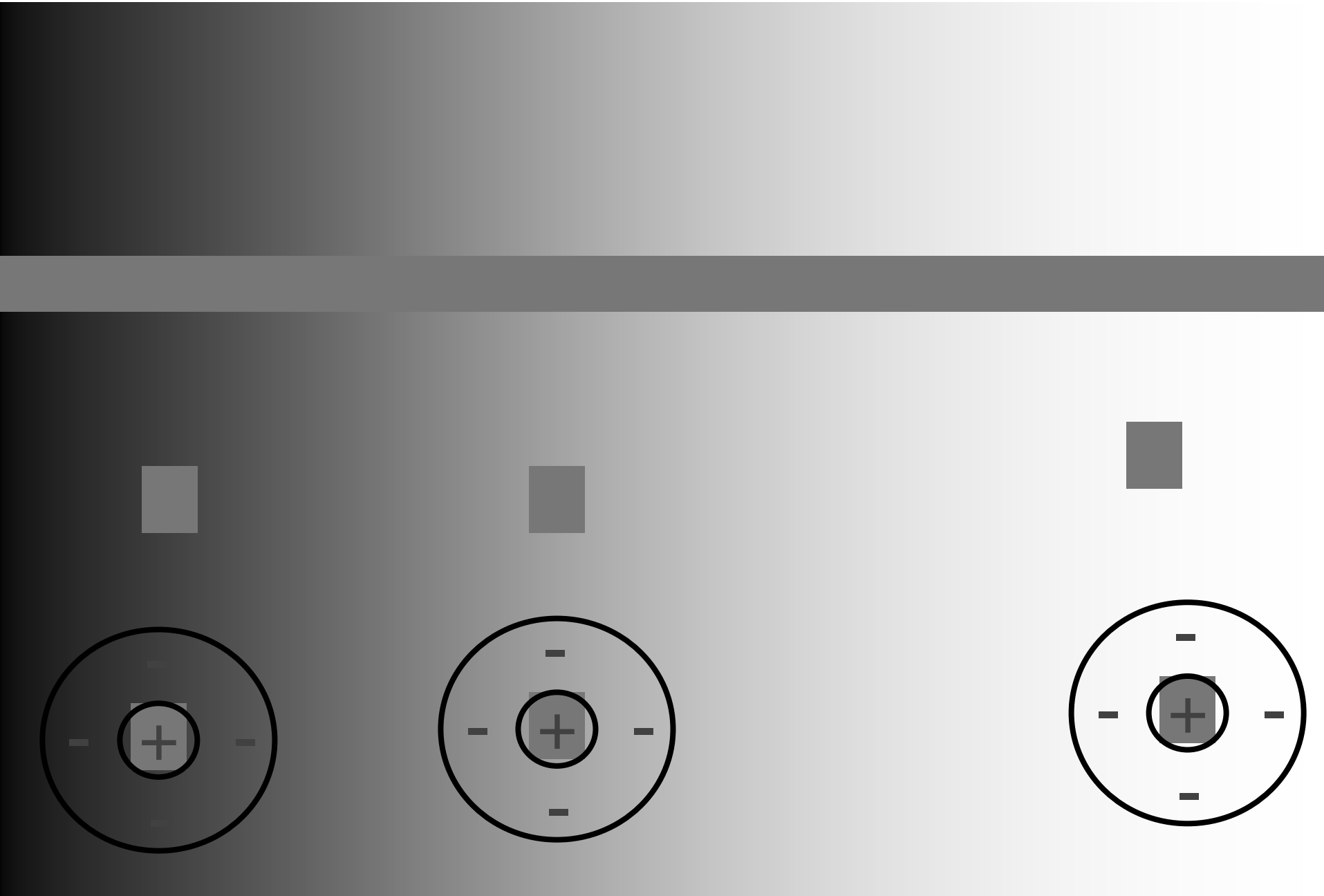
- Reflectance
- Illuminance

- Distal Stimulus
- Proximal Stimulus
- Percept

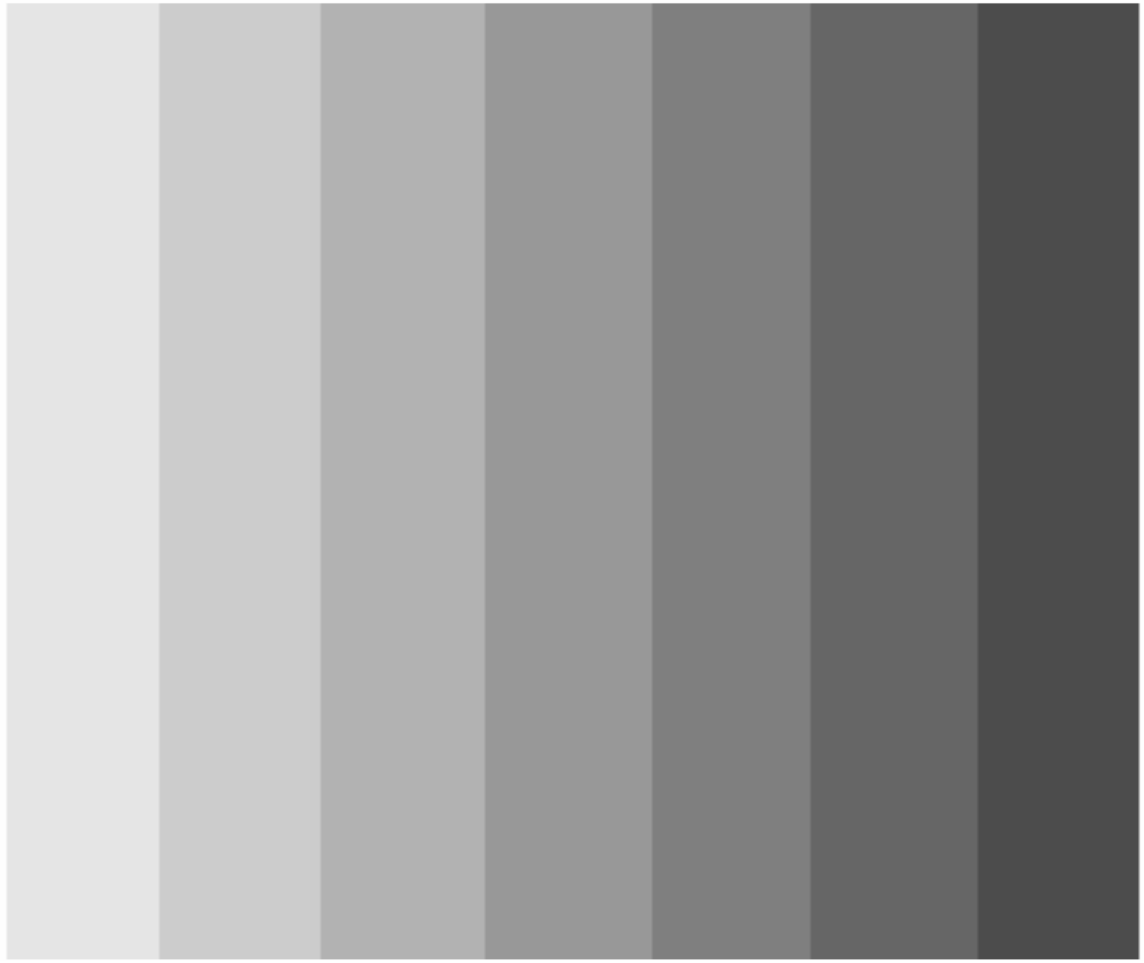
Brightness

The lightness of an object depends on the object's surround

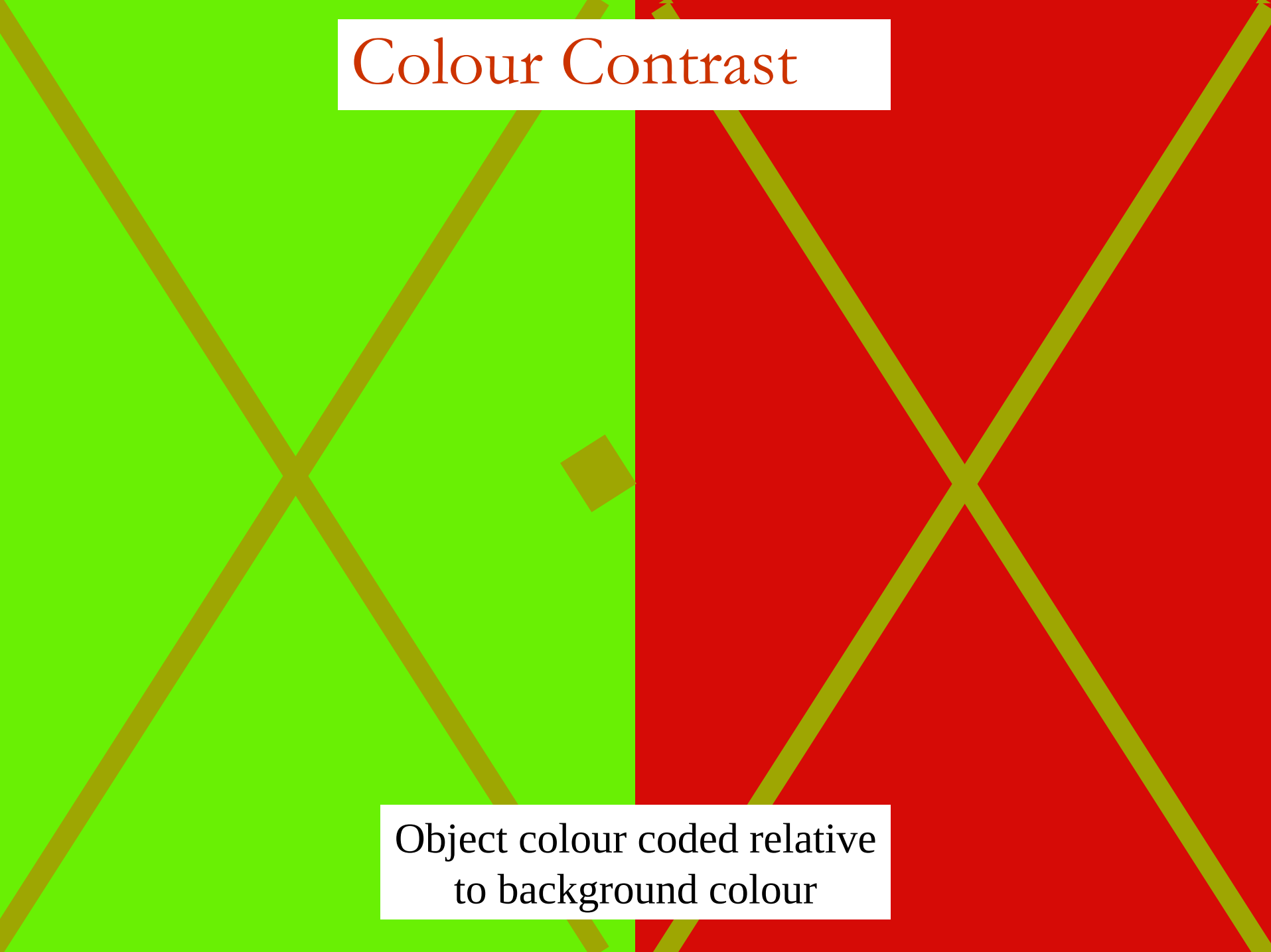
Simultaneous Brightness Contrast



Mach Bands



Colour Contrast

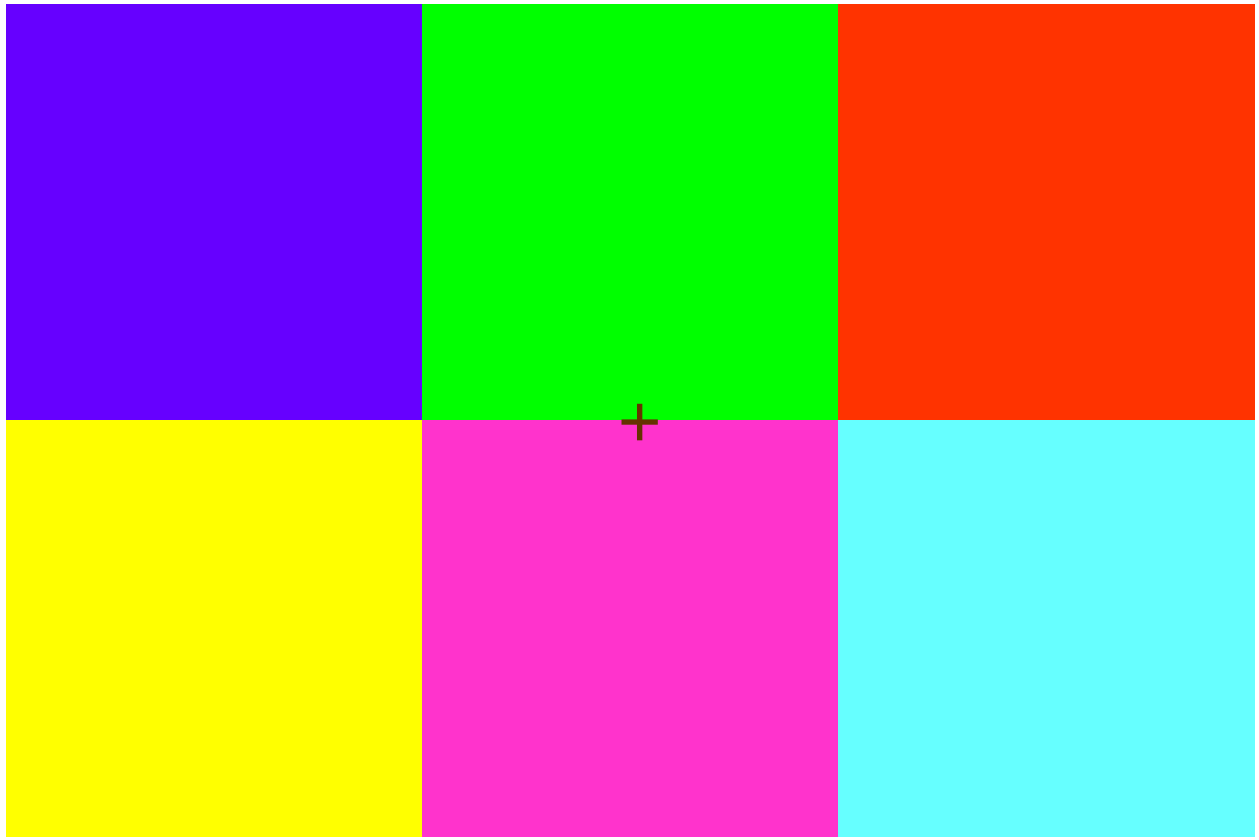


Object colour coded relative to background colour

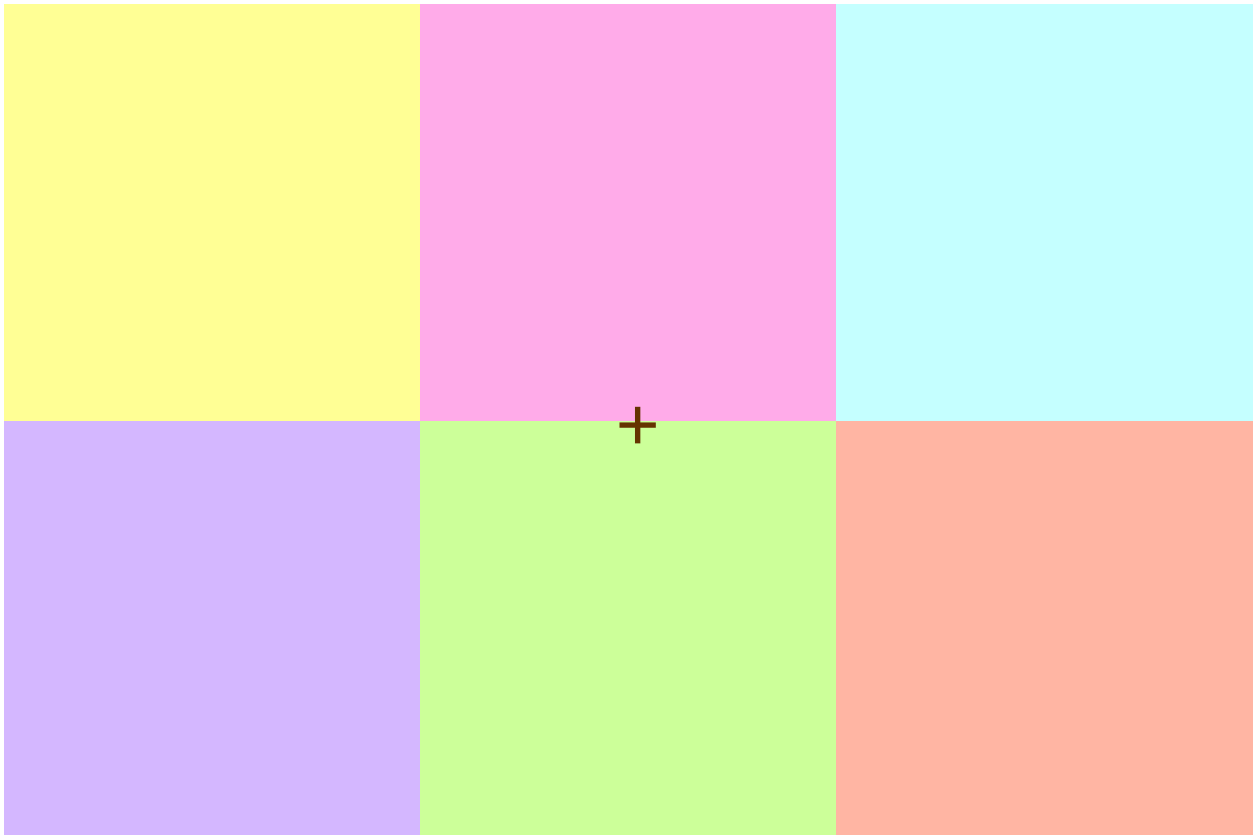
Illusions Over Time

Colour after effect

Colour After Effect



Negative Colour After Images

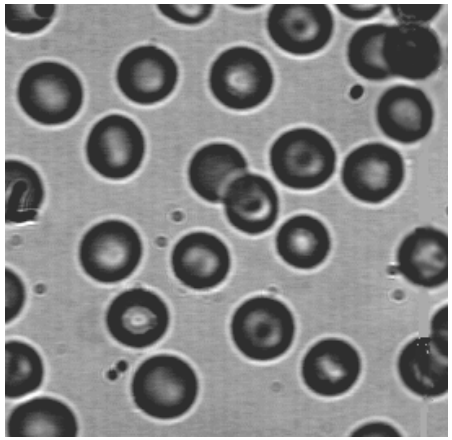


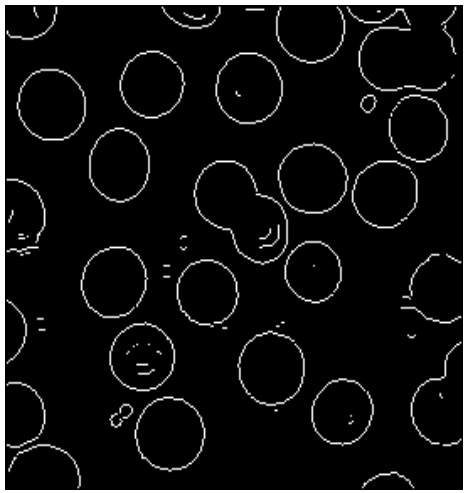
Adaptation

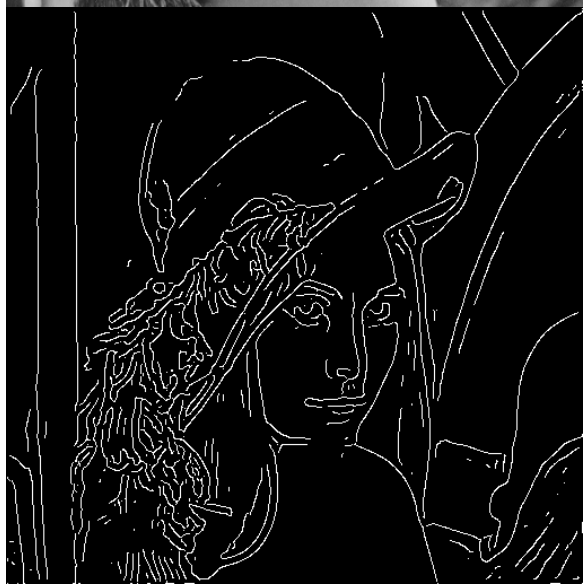
- All of the illusions seen so far depend on fundamental properties of the visual system

- When a stimuli is presented (colour, motion, etc) the visual system adapts to this presentation
- Thus these illusions work because the visual system compensates for a particular stimuli in the reverse direction

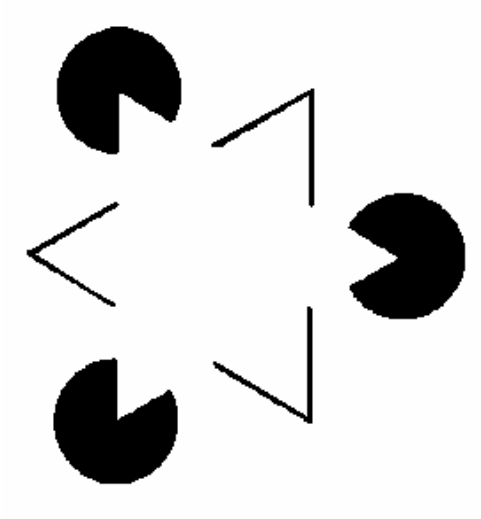
Edge image

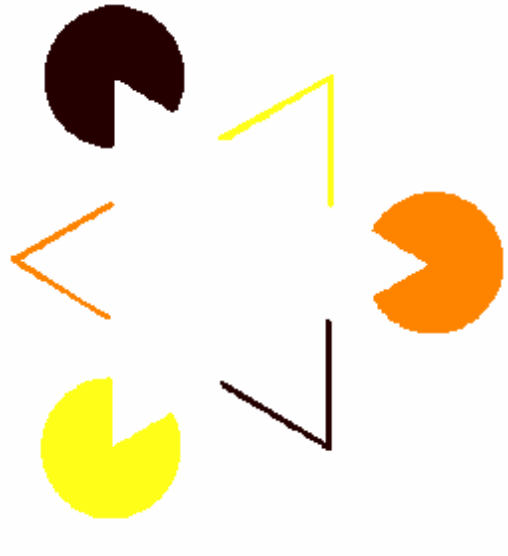






Subjective Contours



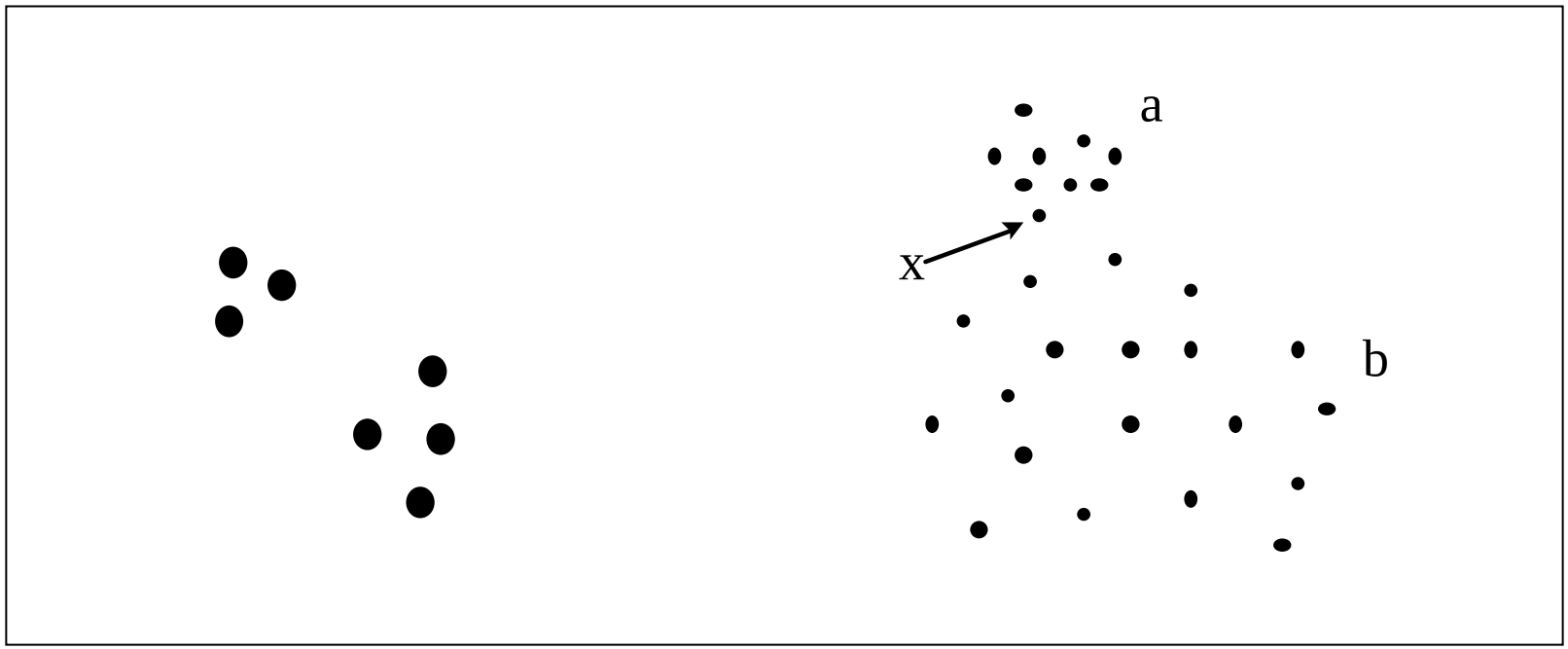


Principles of Grouping

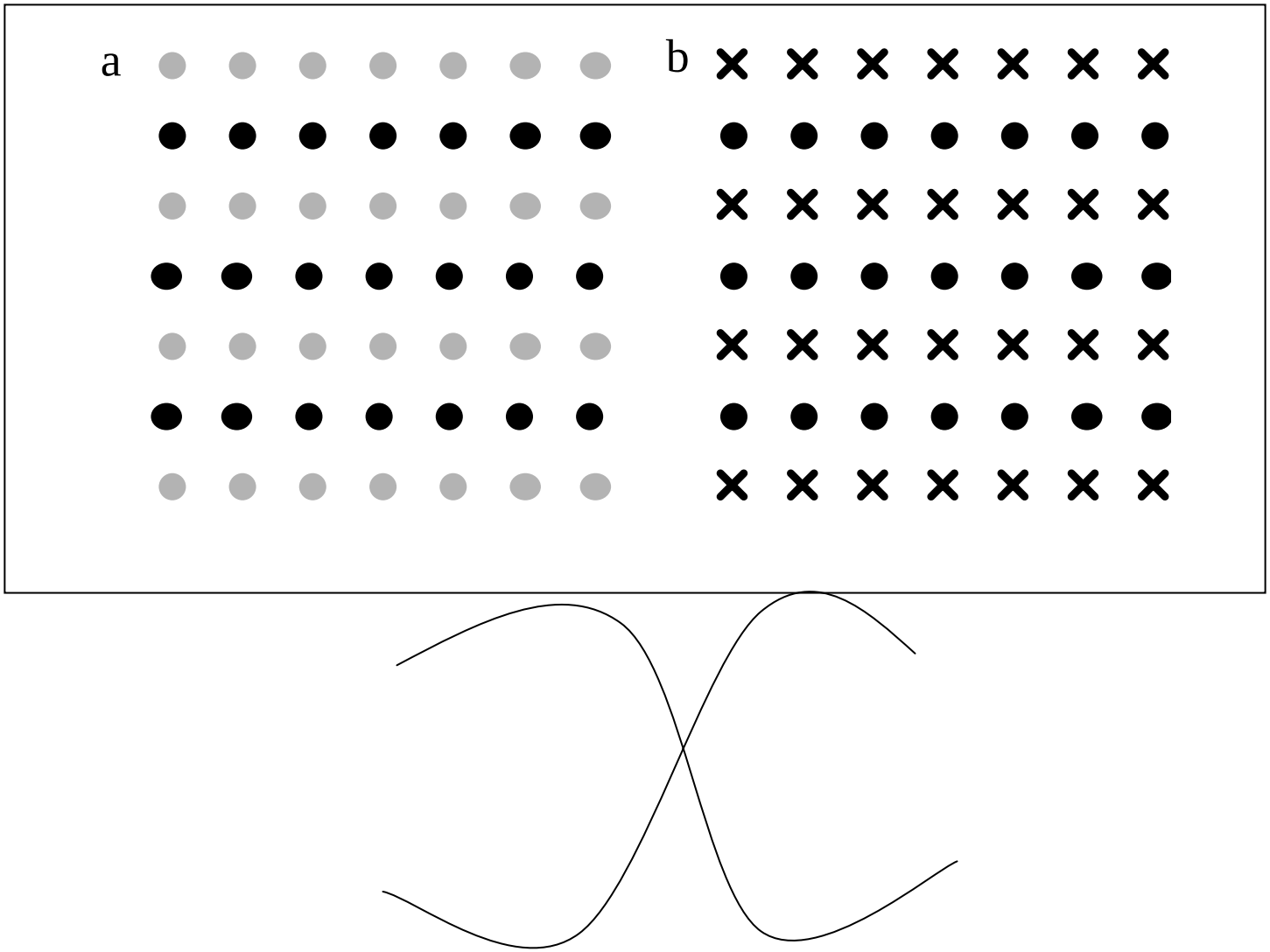
- Gestalt Laws
  - [Max Westheimer, Kurt Koffka, and Wolfgang Kohler (1912)]
- Proximity
- Similarity
- Continuity
- Closure
- Common region
- Figure and ground
- Common fate
- Synchrony
- Element connectedness
- Symmetry
- Parallelism

Proximity

- Emphasize relationship by proximity
- Spatial Concentration

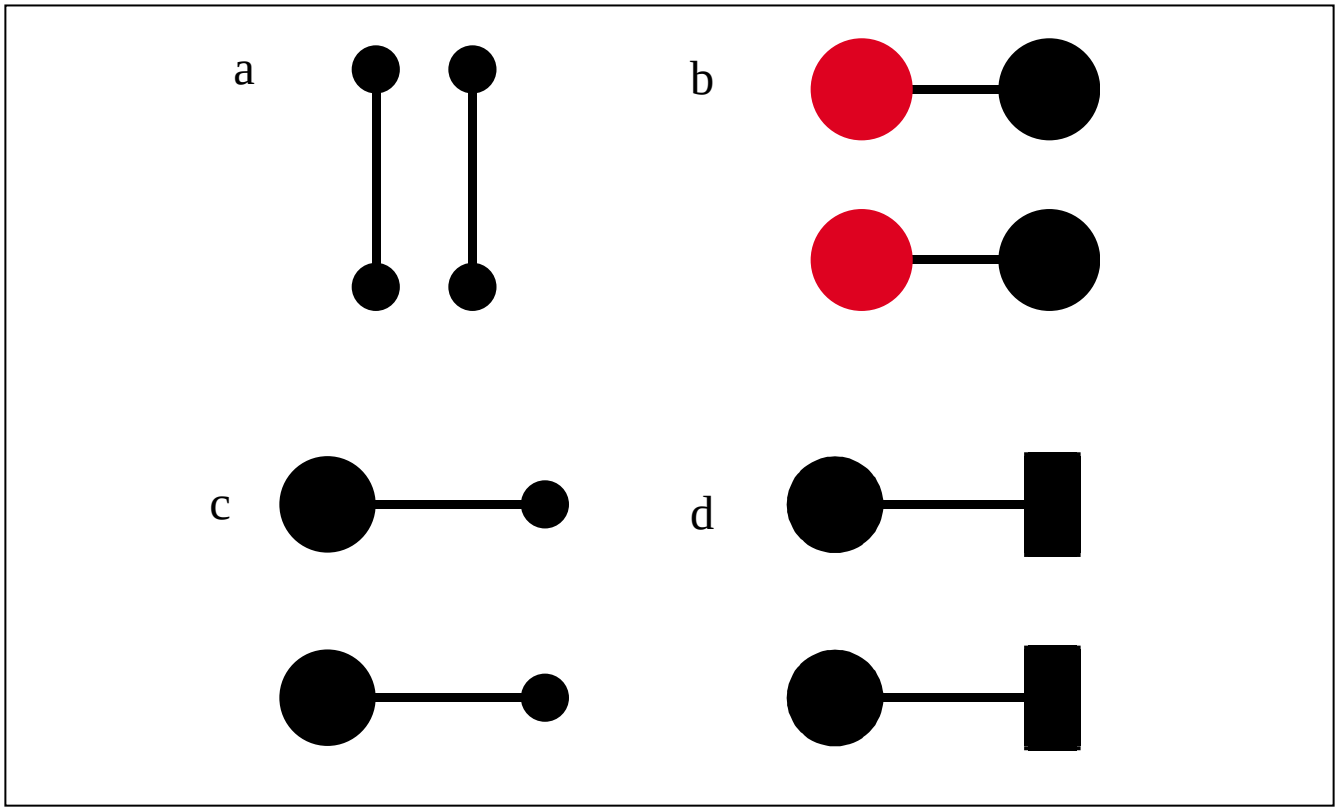


Similarity and Continuity



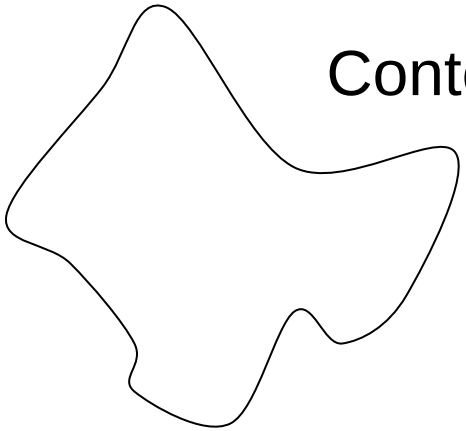
Connectedness

- Stronger than shape, proximity, color

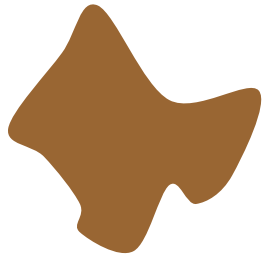


Common Region

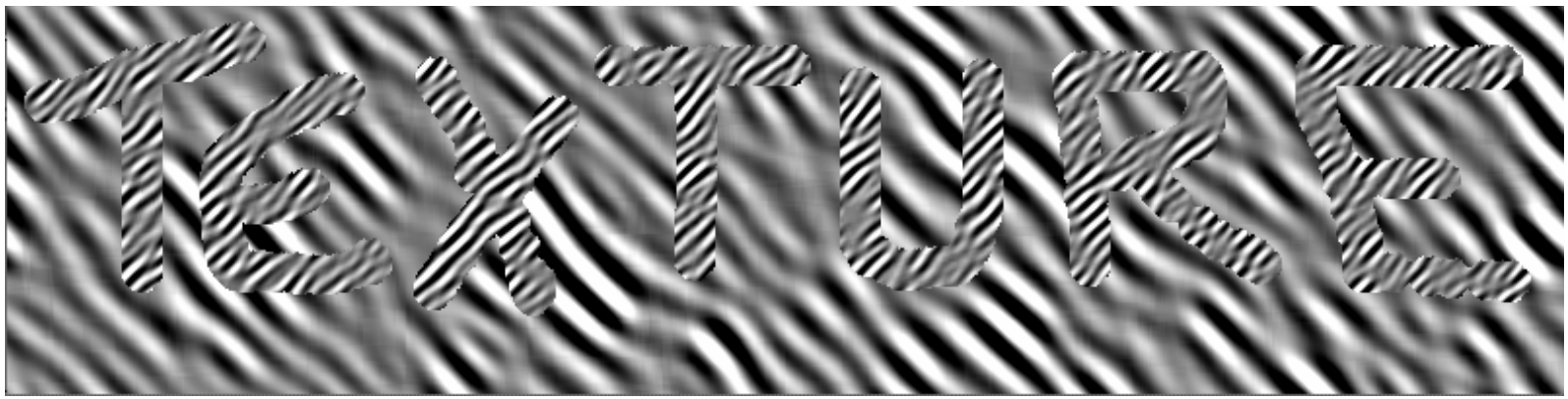
Contour



Color

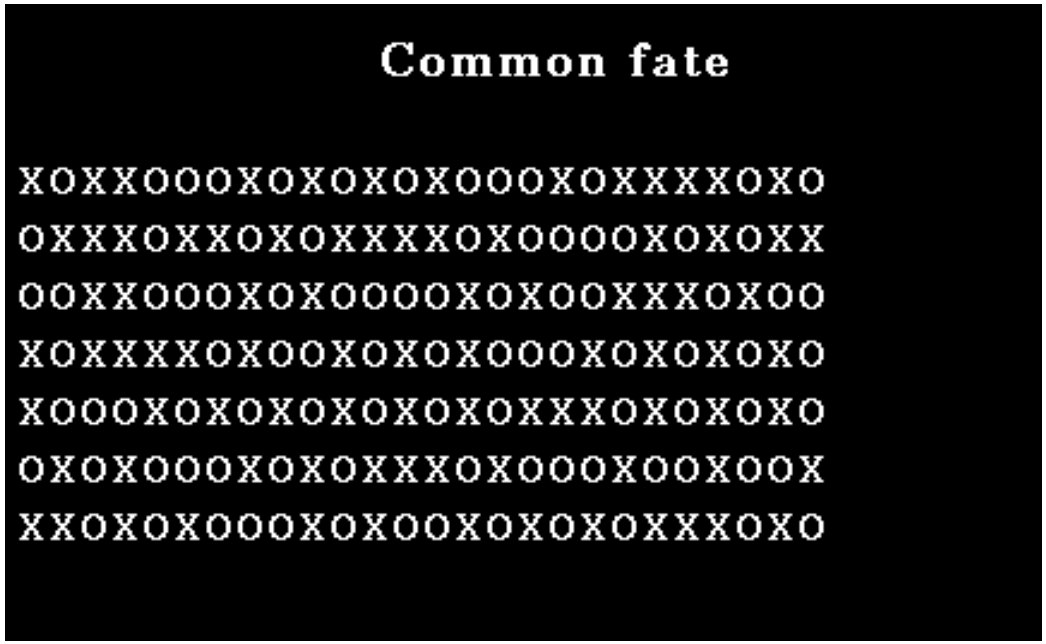


Texture

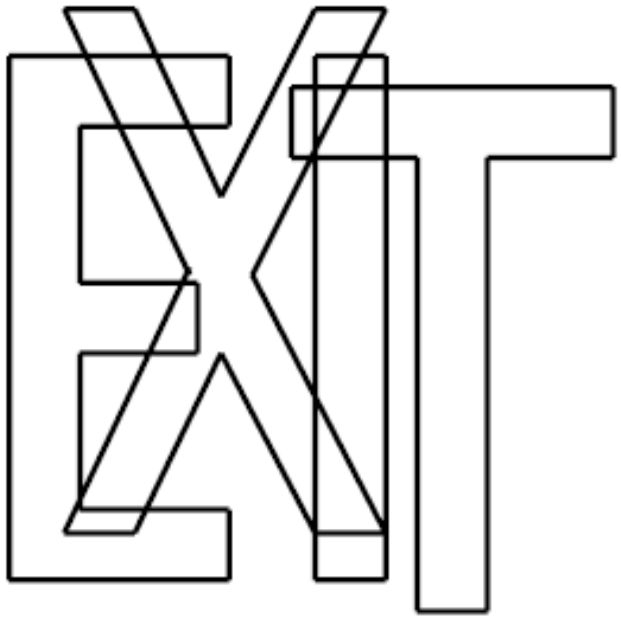


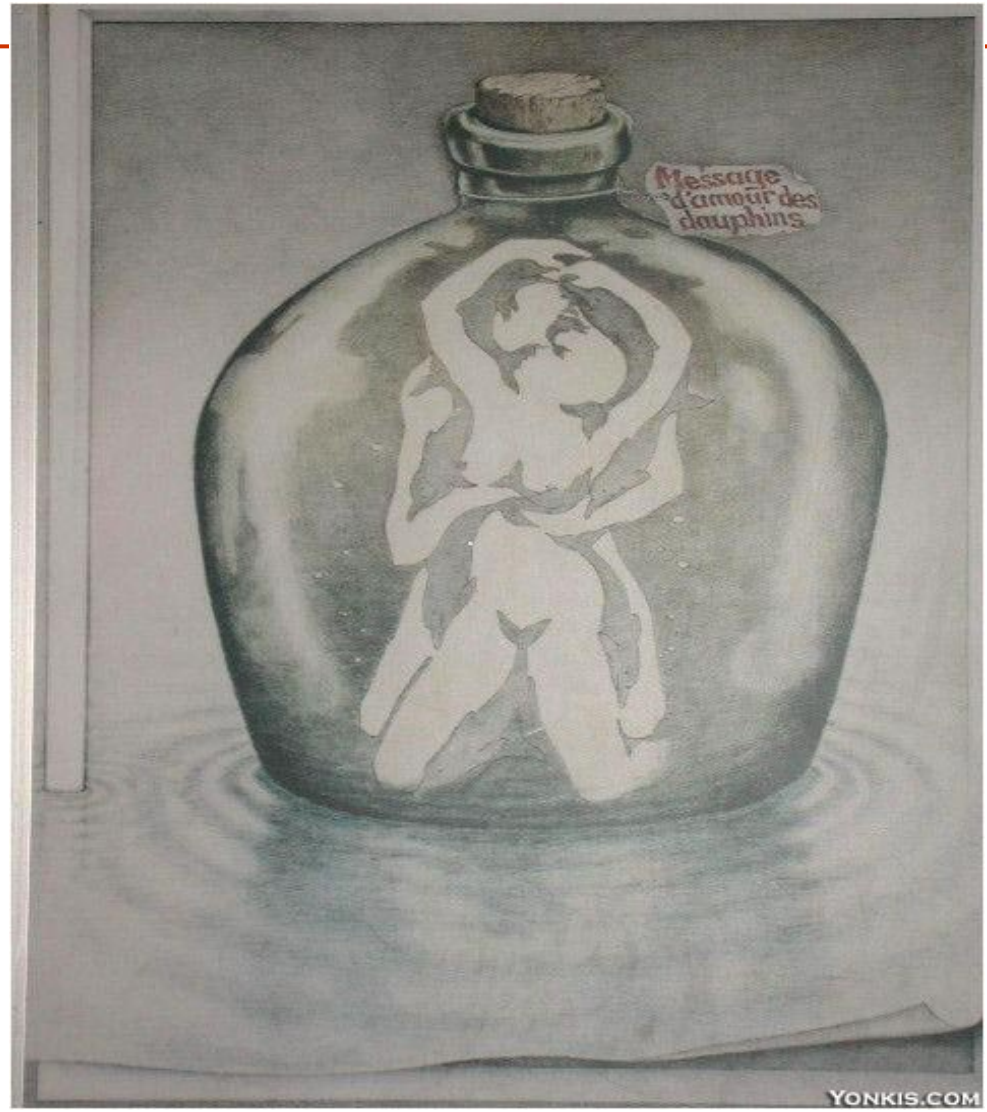
Common fate

- correlation between points:
  - frequency, phase or amplitude
  - Result: phase is most noticeable

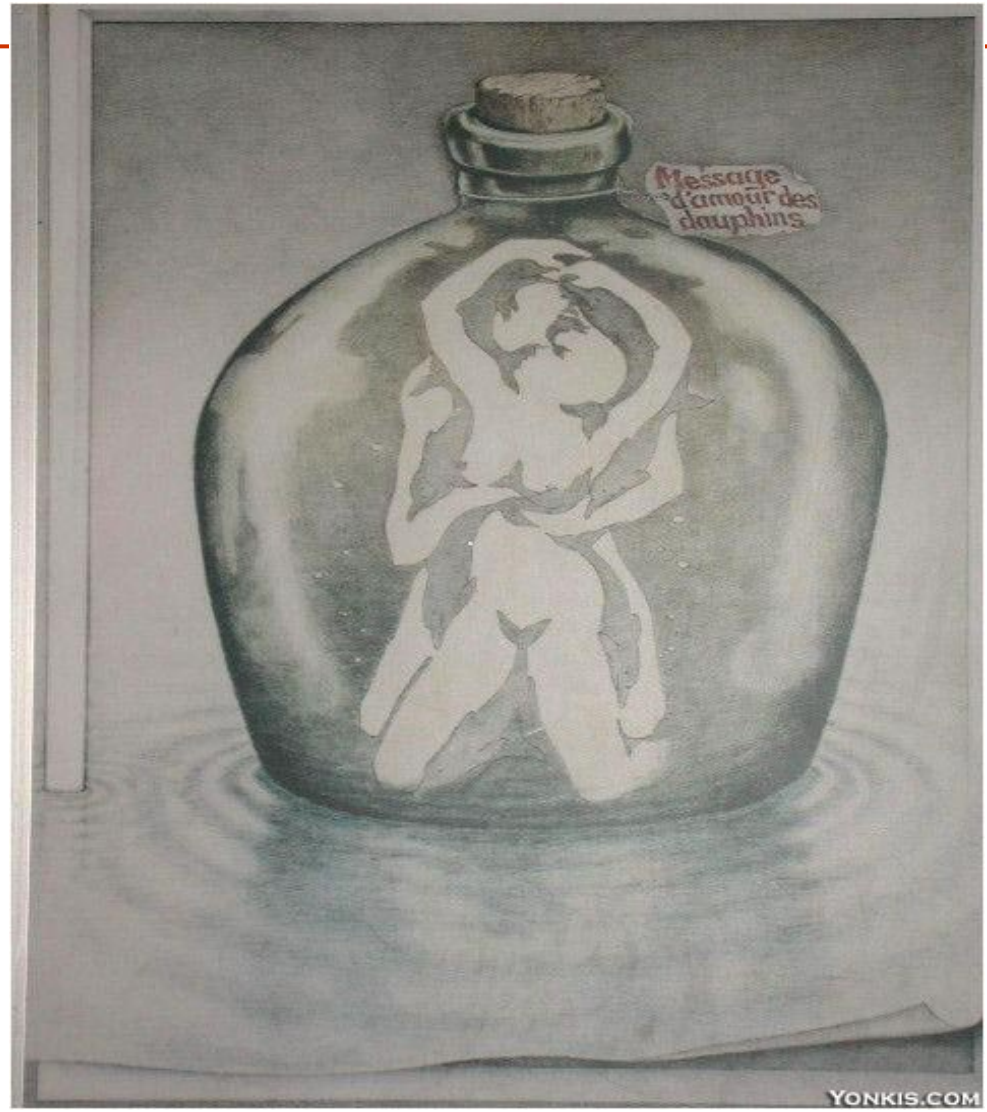


Segmentation




Message d'amour des dauphins
YONKIS.COM

How many dolphins?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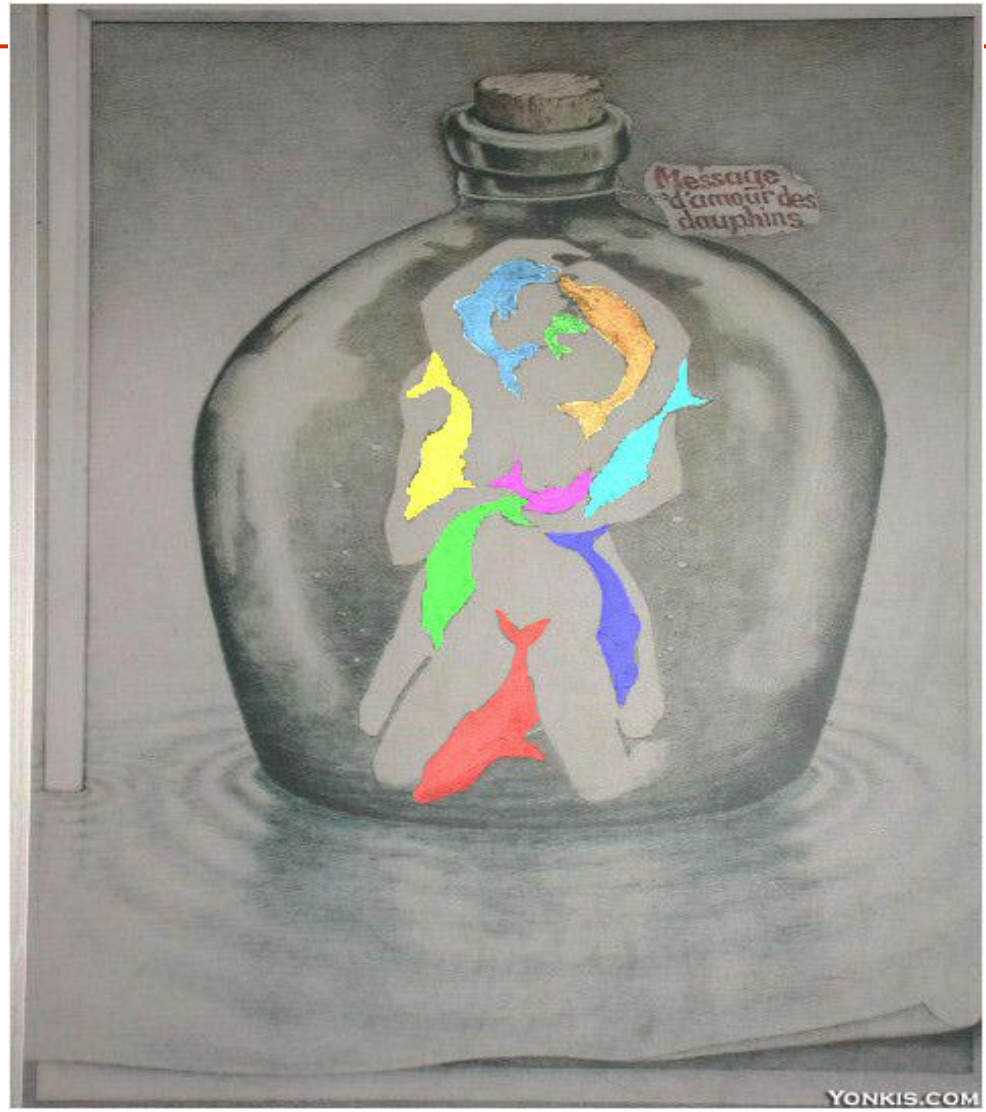
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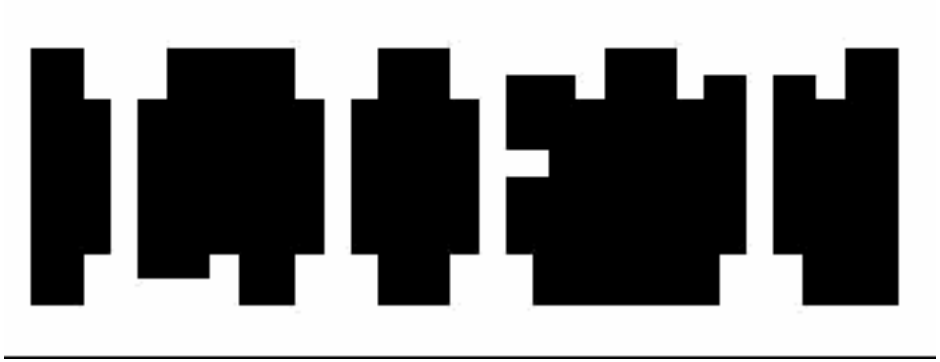
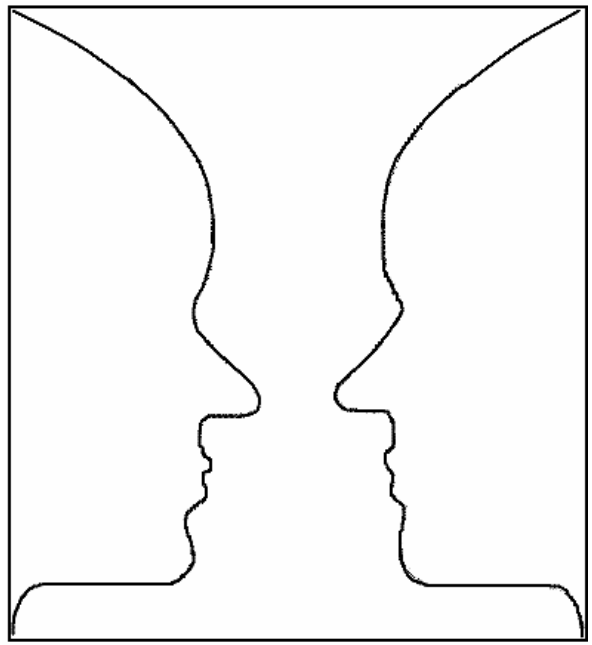


Reversible Figure and Ground

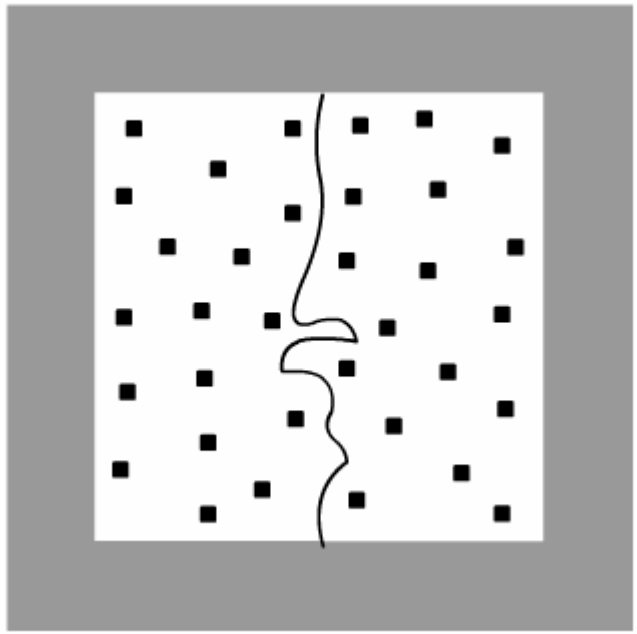


Discovered by Edgar Rubin

Figure-Ground as arising out of M-P interactions

- Magno cells and Parvo cells differ in terms of their color and spatio-temporal sensitivities.
- M-cells are more sensitive for motion, depth, low spatial and high temporal frequency, and low-contrast information (Cavanagh et. al., 1984; Livingstone & Hubel, 1987).
- P-cells are comparatively more responsive for the color, form, high spatial and low temporal frequency, finer detail and high contrast information (Logothetis et al., 1990).

Temporal Frequency & Figure/Ground



Form Detection

- luminance
- Color
- Contour
- Texture
- Stereopsis
- Motion
- Shading

Color and SFM

The Thatcher Illusion

The Thatcher Illusion

Features analysed independently

Each feature coded relative to gravity

Hollow face illusion

Attention

- What is Attention?
- Different types of attention
- What is attention for?

Selective Attention

- The central concept will be the notion of “picking out” or selecting and the usual mechanism that is appealed to in explaining this selection is attention (sometimes called focal attention or selective attention).
- Why do we need to select?
  This is a nontrivial question and we will consider several different answers:
  - We need to select because we can’t process all the information available. This is the resource-limitation reason.
  - We need to select because of the way relevant information in the world is packaged. It gives rise to the Binding Problem
  - We need to select because certain patterns cannot be computed without first marking certain special elements of a scene
  - We need to select because selection is the first line of contact between the mind and the world – and precedes all conceptualizing and encoding

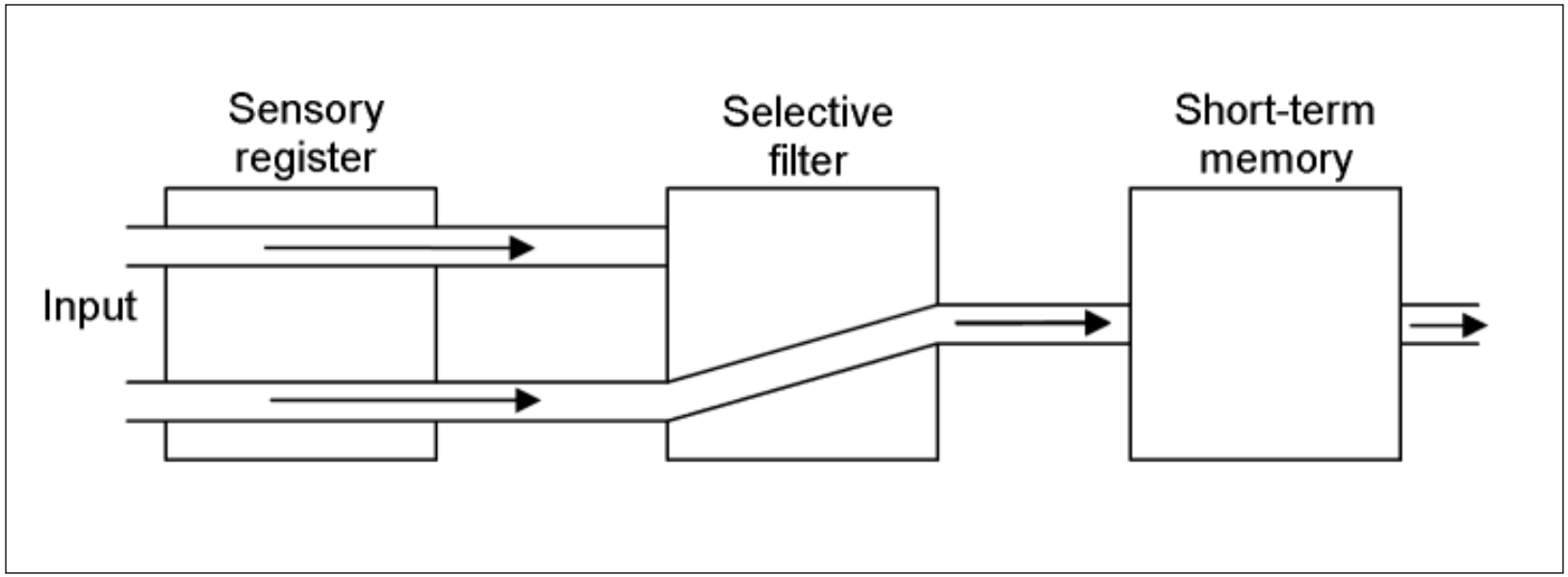
Attention as Selection

- We can concentrate on the Selection or Filtering aspects of attention. We ask:
- Why do we need to select anyway?
  - Because our processing capacity is limited?
- On what basis do we select? Some alternatives:
  - We select according to what is important to us (e.g., affordances)
  - We select what can be described physically (i.e., “channels”)
  - We select based on what can be encoded without accessing LTM
  - We “pick out” things to which we subsequently attach concepts: i.e., we pick out objects (or regions?)
- What happens to what we have not selected?

Broadbent's Filter Model

- Donald Broadbent (1958) proposed a filter model of attention to account for these findings.
- He argued that we filter out sensory information before it reaches short term memory.
- And that this filtering is based on the physical characteristics of the stimuli.
- Rather than any semantic content.

Broadbent's Filter Model



- In this model, meaning is only processed when we become conscious of the stimuli.
- i.e. after is has got through the filter.

Late Selection Models

- The last two are known as 'early selection models' because information is selected before it reaches awareness and short term memory.
- Deutsch and Deutsch (1963) have argued for a 'late selection model'.
- This is where all information reaches short term memory, but the selection happens at that point.
- Supported by experiments that have shown (?) semantic analysis can happen with unattended stimuli.

Consciousness

- Types of Consciousness
- Functionalist aspects of consciousness
  - Attention and Consciousness
- Neuroscience of Consciousness
  - Blindsight
  - Rivalry
  - Backward Referral

Consciousness – Definitions/Types

- One main difficulty with consciousness is defining
- what we are talking about:
  - Do we mean awareness (e.g., awake vs. asleep)?
  - Qualia (what-it-is-like)?
  - Noticeability (i.e. conscious as opposed to subconscious)?
  - Introspection (reporting on your internal states)?
  - Self-awareness (known who/what you are; self vs. other)?
- Phenomenal vs Access Consciousness (Ned Block)
- Indian – Cit/Purusha/Atman/Brahman
- These various meanings make sweeping claims about consciousness difficult to verify or adjudicate.

Function of Consciousness

- What can consciousness do?
  - Integration
  - Global broadcasting
  - Better control
  - Freewill (Inhibition of Behavior)
  - Self monitoring & communication

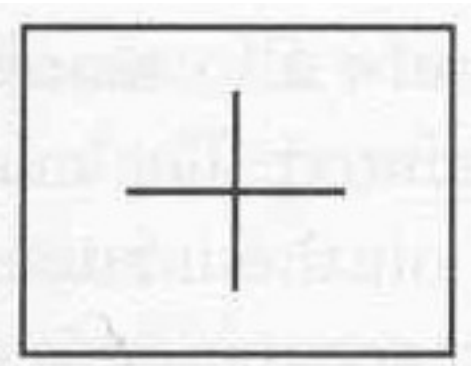
Attention and Consciousness

- Are they same or different
- What is the relationship?

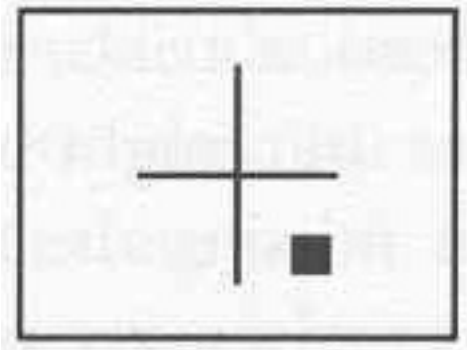
Inattentional Blindness

Mack & Rock (1998)

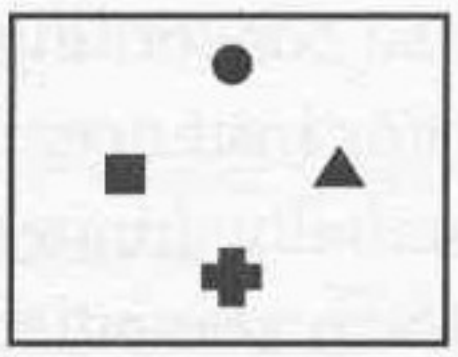
- Definition: the failure to see consciously, caused by lack of attention
- We can miss perceiving very obvious changes if we are not attending. Subjects do not consciously perceive features of the visual scene that they do not attend to.
- Subjects were engaged in tasks that demanded a high degree of attention, such as looking at a cross and trying to determine which arm is longer.



Trials 1-3



Inattention Trial



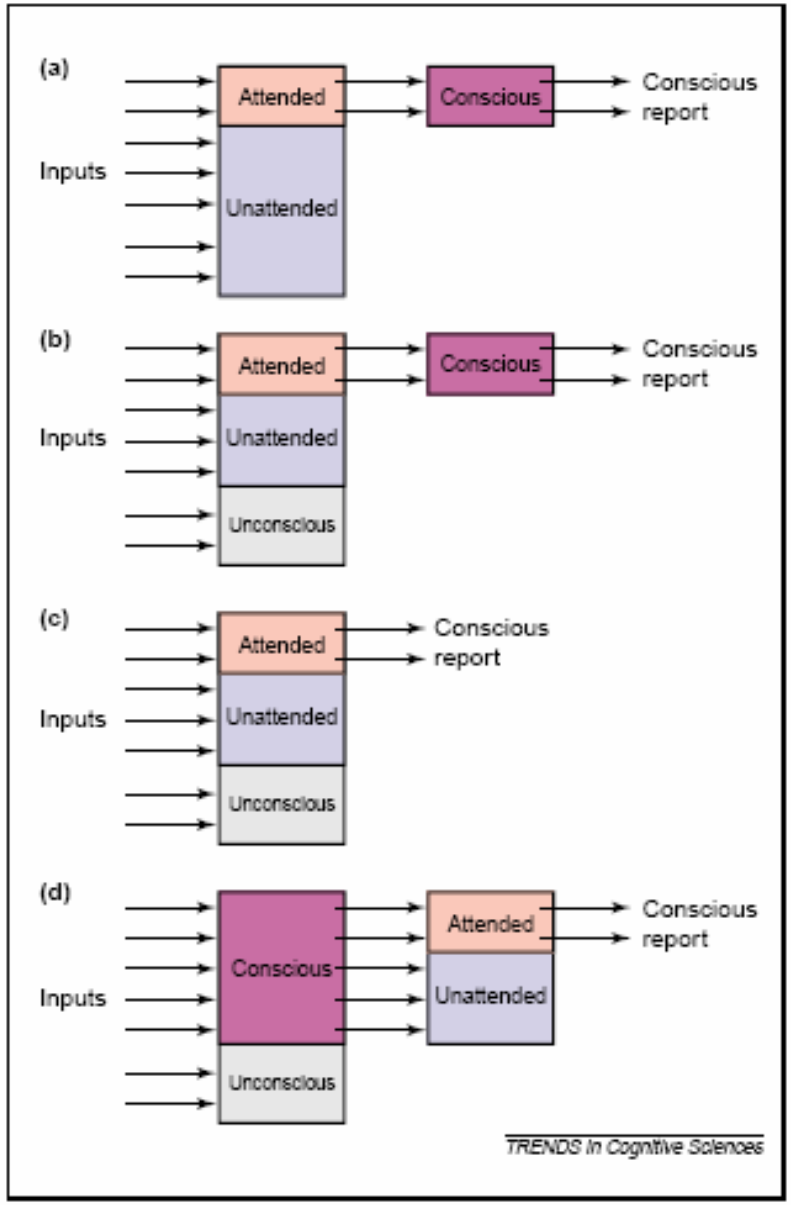
Recognition Test

Change Blindness

- “Visual perception of change in an object occurs only when that object is given focused attention”
- “In the absence of such attention, the contents of visual memory are simply overwritten by subsequent stimuli, and so cannot be used to make comparisons”

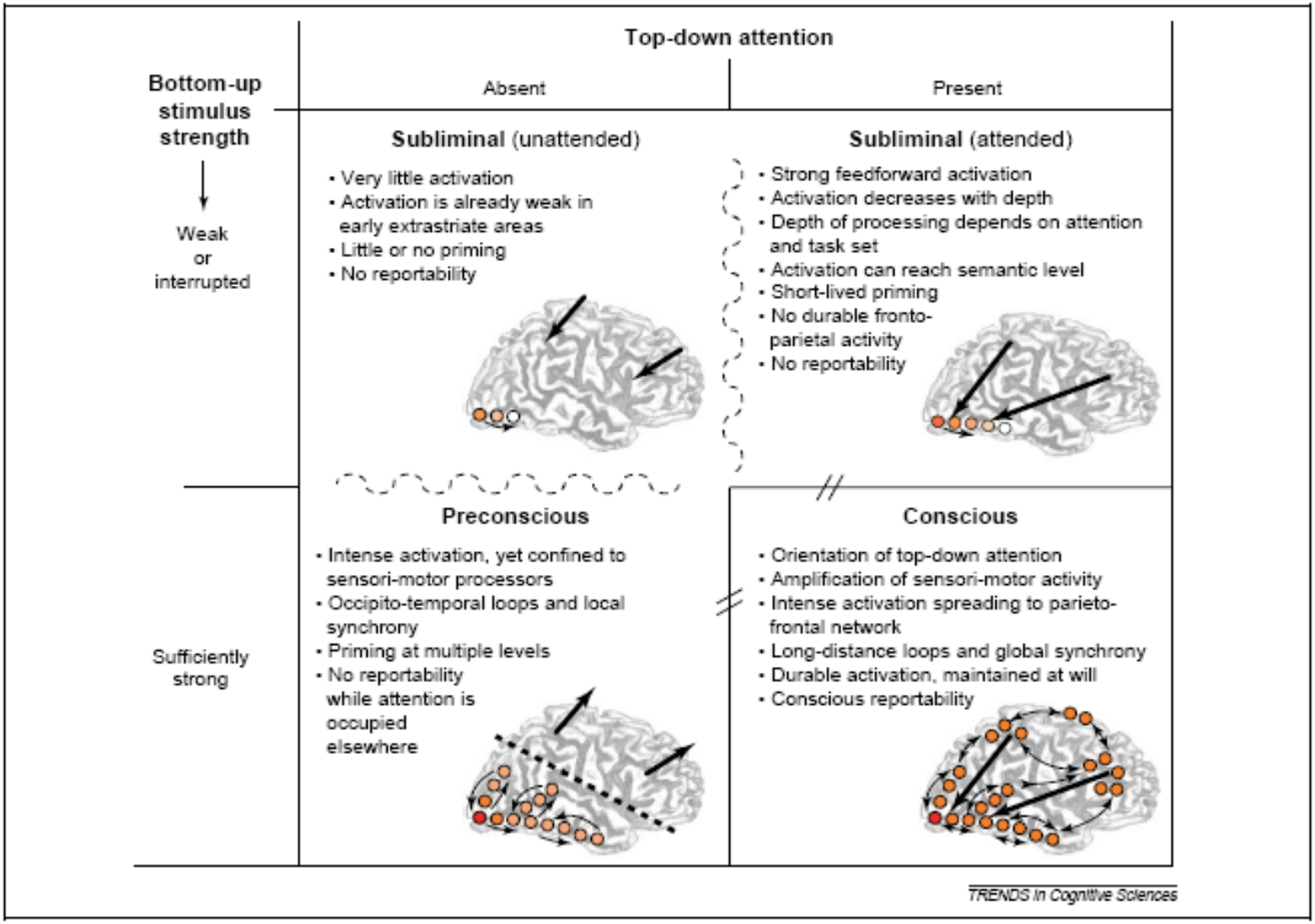
CB – Another Example

Attention and Consciousness (1)



Lamme, 2003

Attention and Consciousness (2)



Dehaene et al., 2006

Attention and Consciousness (3)

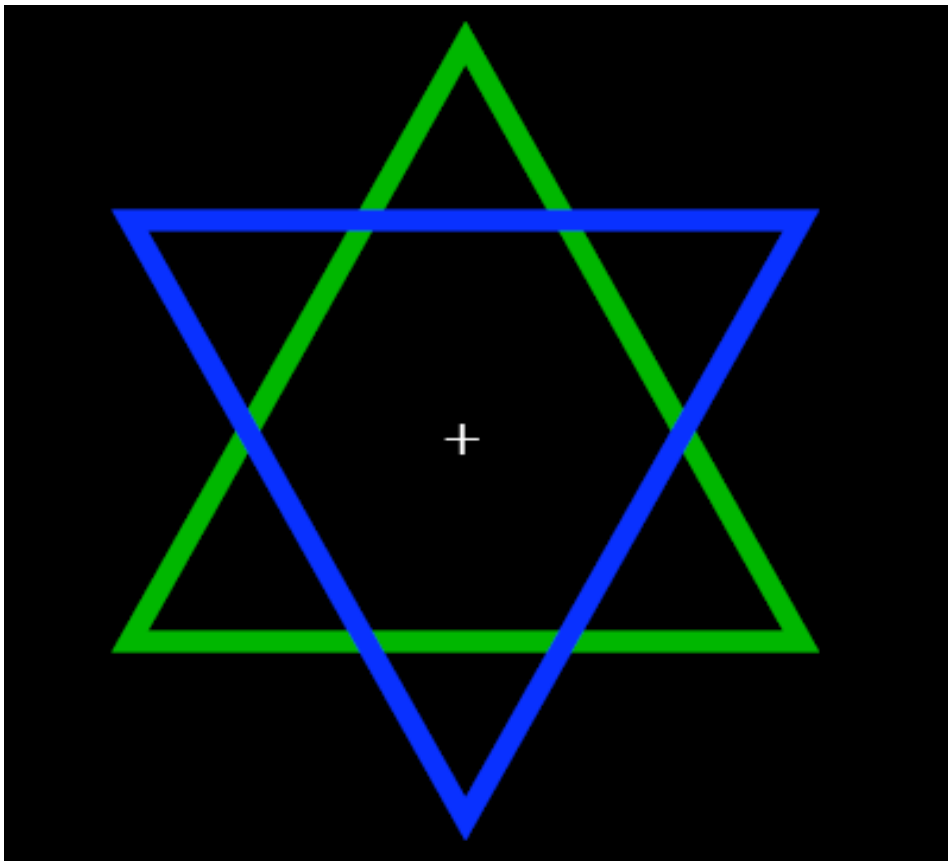
	May not give rise to consciousness	Gives rise to consciousness
Top-down attention is not required	Formation of afterimages Rapid vision (< 120 ms) Zombie behaviors	Pop-out Iconic memory Gist Animal & gender detection in dual-tasks Partial reportability
Top-down attention is required	Priming Adaptation Visual search Thoughts	Working memory Detection and discrimination of unexpected & unfamiliar stimuli Full reportability

Koch & Tsuchiya, 2007

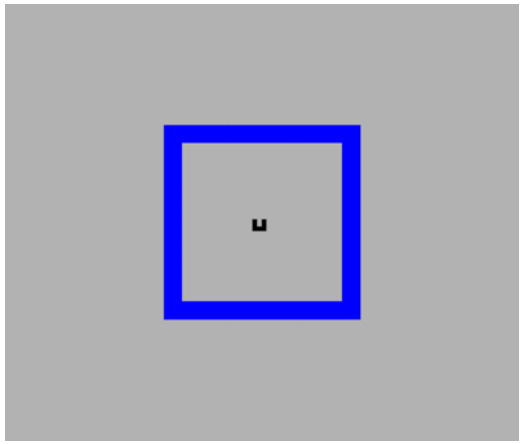
Types of attention

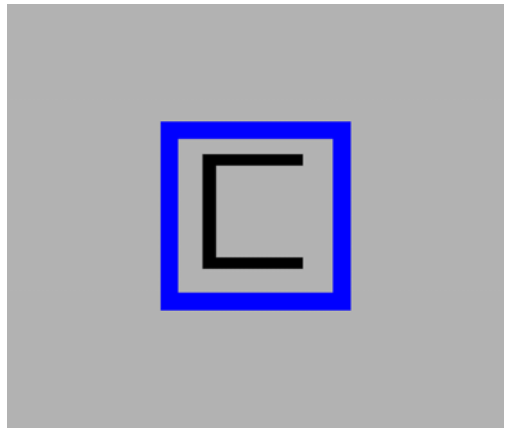
- Focused vs Distributed Attention
- Distributed attention has been shown to facilitate statistical processing of stimuli (Demeyere & Humphreys, 2007, Treisman, 2007).
- Gist of a scene might be obtained by distributing attention over the whole scene.
- Average size or numerosity judgments could be obtained via distributed attention mechanisms (although see Myczek & Simon, 2008).
- Distributed attention might be better for processing at larger spatial scales than smaller spatial scales.

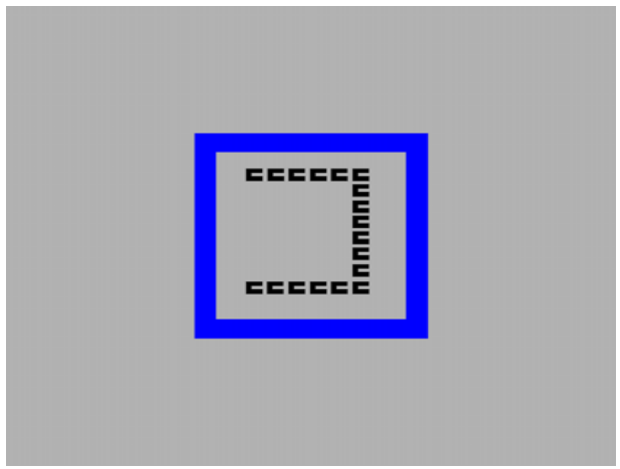
Afterimages



Stimuli







Thanks

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