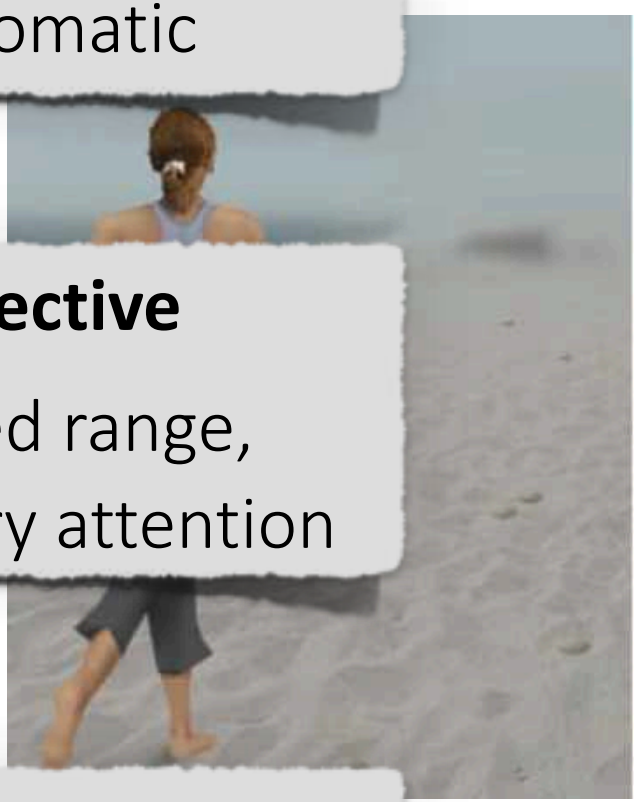
CSE485: Introduction to Cognitive Science

Vinoo Alluri

Nature of Perception

rapid and **effortless** that it appears automatic

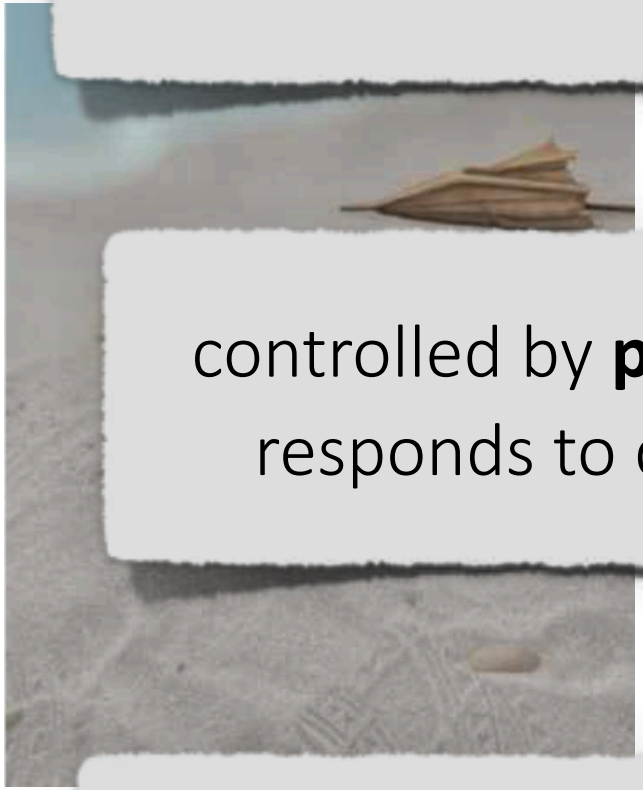


selective

limited range, voluntary attention

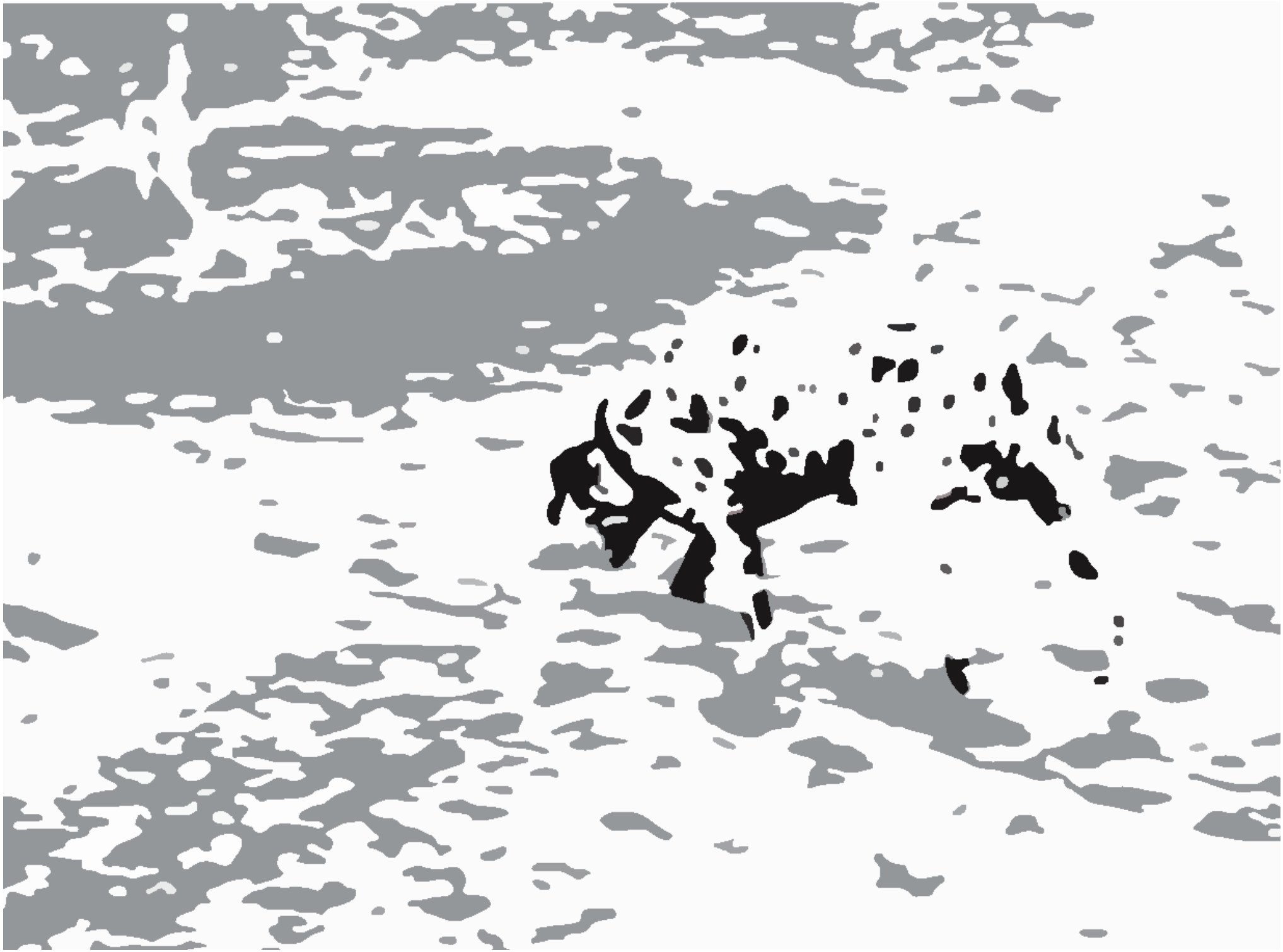
involves a **reasoning** process

adaptive - appropriate to the environment

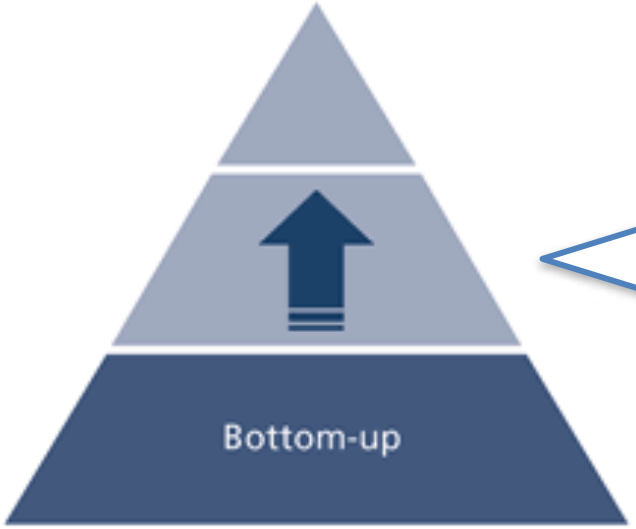


controlled by **patterns** - responds to change

a **dynamic** process that is accompanied by action



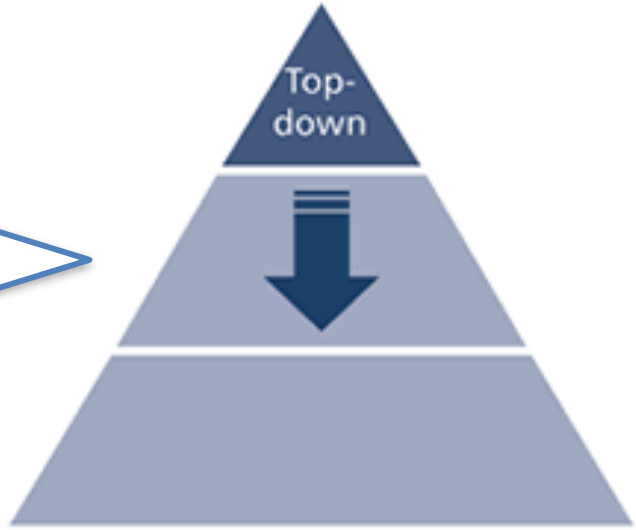
BOTTOM-UP



“what do i see?”

- begins with stimulus - it influences what we perceive
- taking sensory information and then assembling and integrating it
- **data**-driven

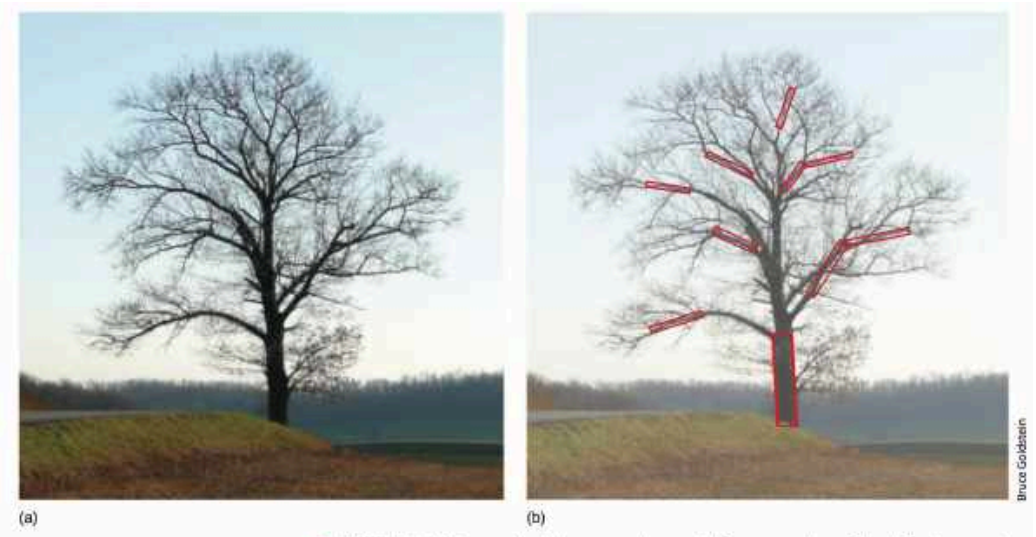
TOP-DOWN



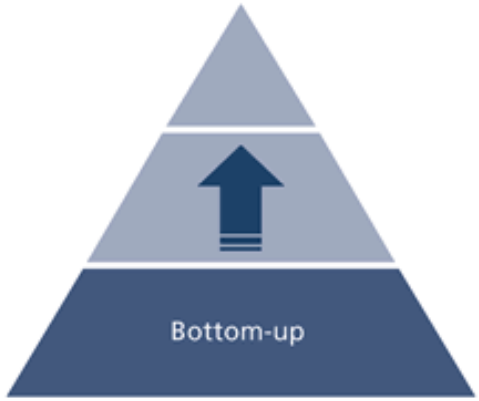
“have i seen this before?”

- prior knowledge/experience influences perception
- using models, ideas, and expectations to interpret sensory information
- **theory**-driven

BOTTOM-UP

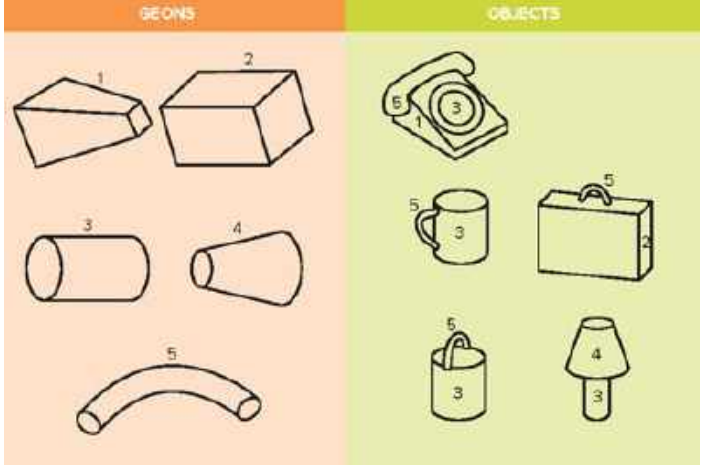


● **FIGURE 3.2** A tree such as this one can be created from a number of simple features, such as oriented bars (a few of which are highlighted on the right). When a person looks at the tree, each feature can activate feature detectors in the cortex that respond best to specific orientations. This occurs at an early stage of cortical processing.

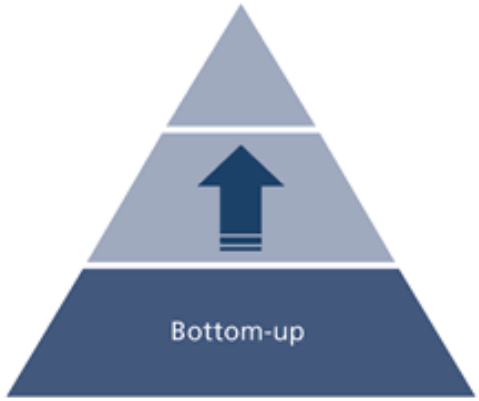


physiological

- neurons in the cortex that respond best to simple shapes like lines or bars with specific orientations are called feature detectors because they respond to simple features
- feature detectors' response is the first step in the brain's response to objects



BOTTOM-UP

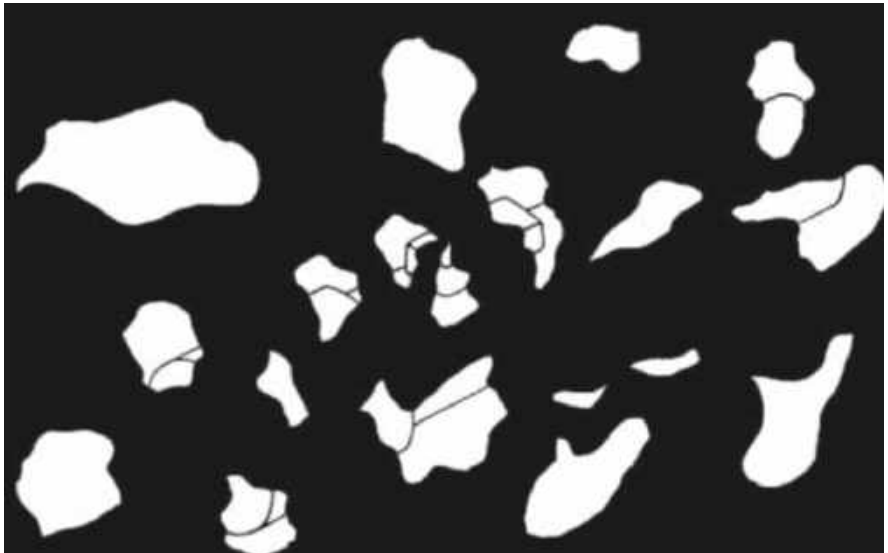


behavioural

recognition-by-components (RBC) theory

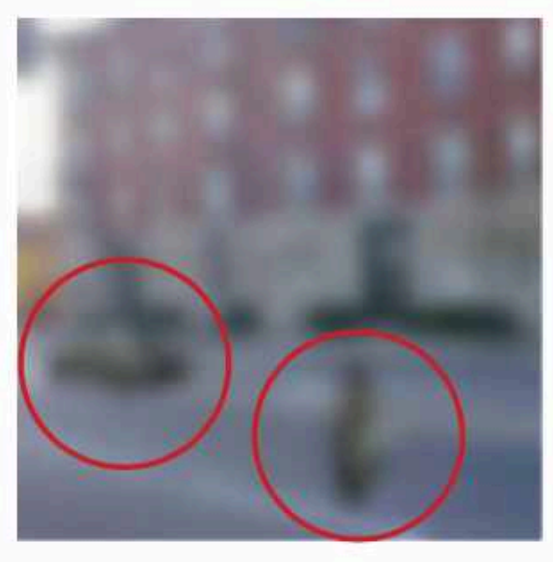
geons - perceptual building blocks (Biederman, 1987)

principle - if we can recover (see) an object's geons, we can identify the object



CONTEXT MATTERS

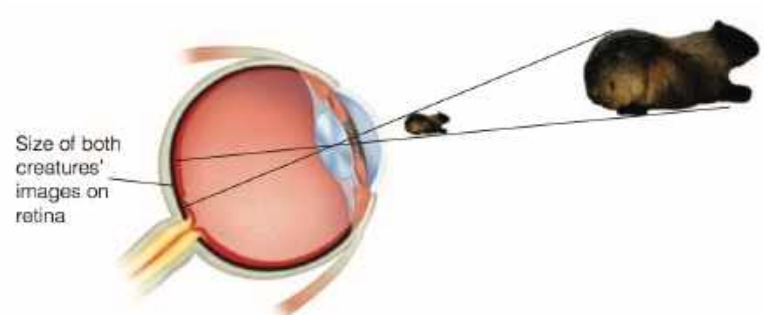
Multiple personalities *of the blob!*



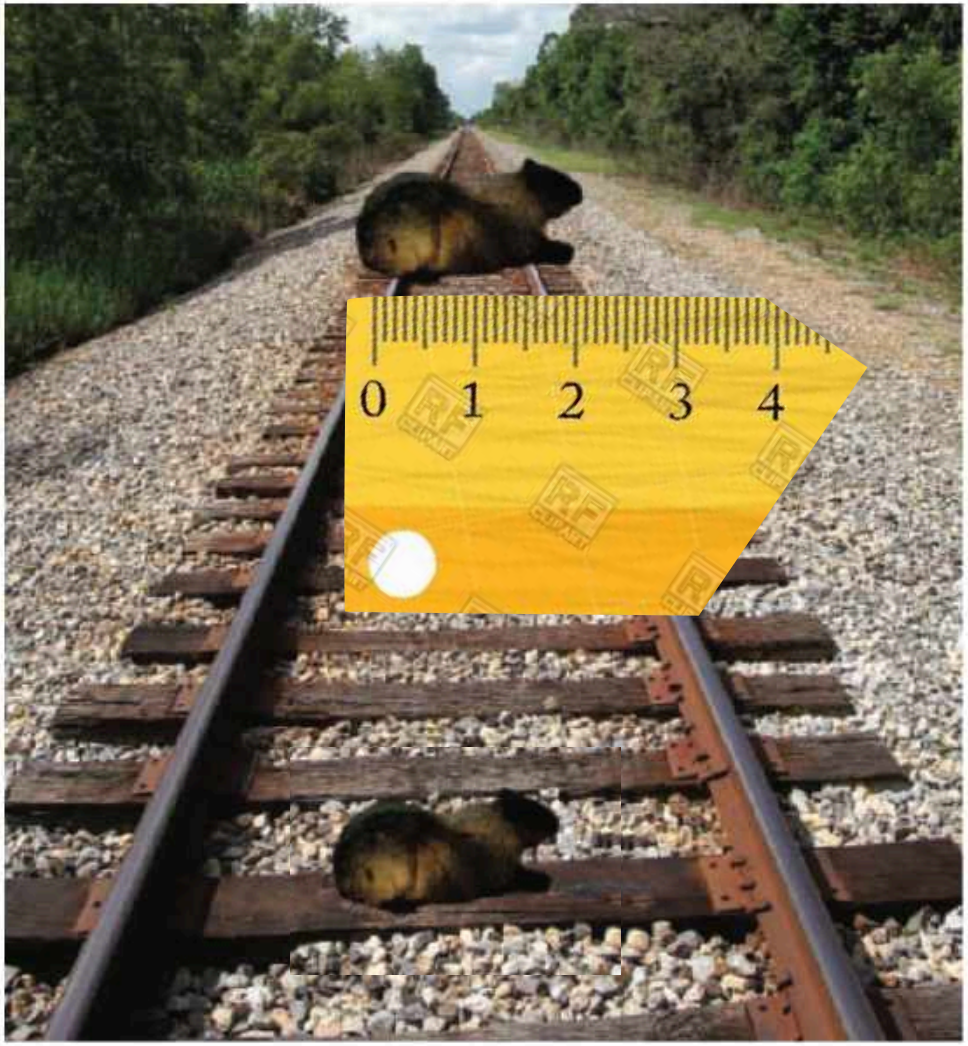
TOP-DOWN

ex: higher-level brain areas "prime" the low level areas to detect that pattern

CONTEXT MATTERS



TOP-DOWN

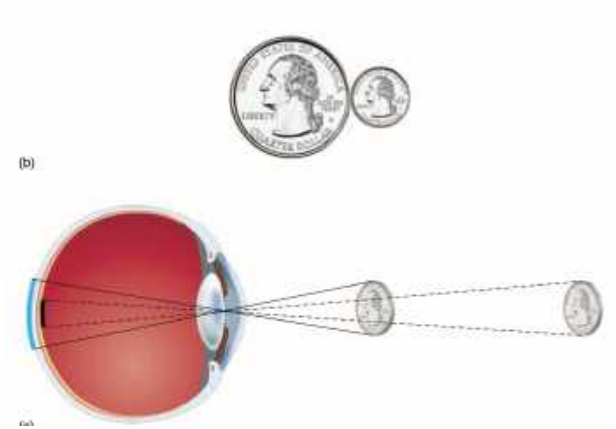


Perceptual Constancy

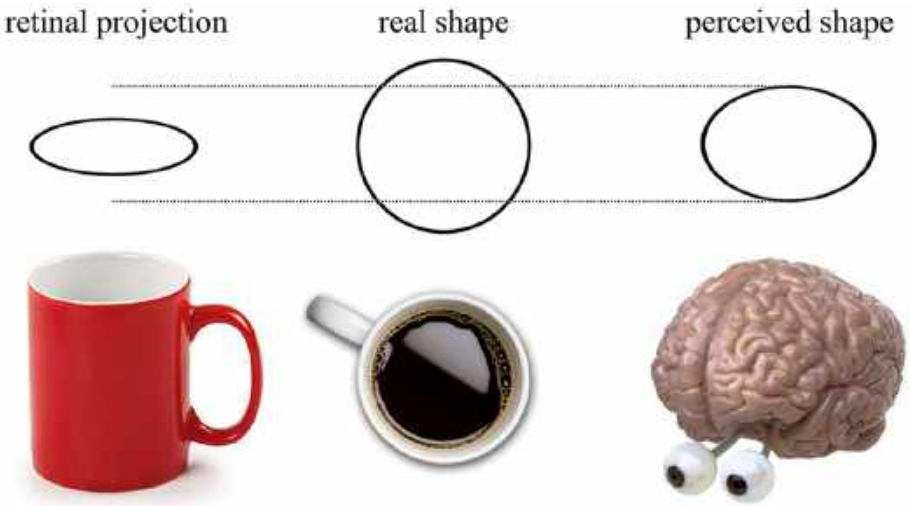
- The tendency to perceive objects as maintaining stable properties (e.g., size, shape, brightness, and color) despite differences in sensory input: distance, viewing angle, and lighting
  - **Size constancy**
    - perceiving objects as being about the same size when they move farther away or are spaced
  - **Shape constancy**
    - perceiving objects as having a stable or unchanging shape regardless of changes in the retinal image resulting from differences in viewing angle

Perceptual Constancy

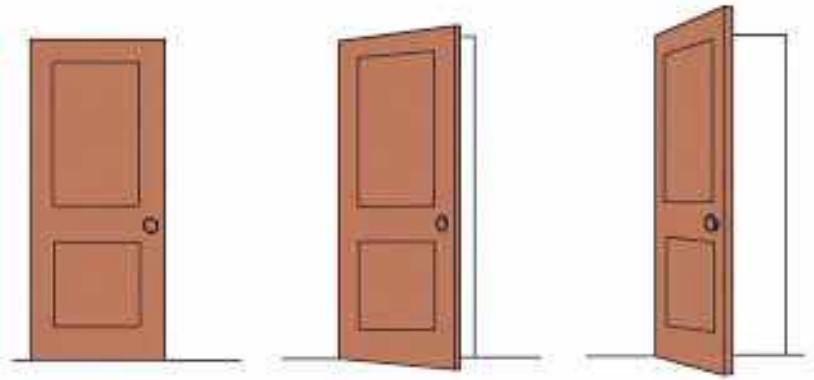
Size



Shape



"A door is a door is a door"



Perceptual Constancy

- **Timbre constancy**
  - A friend's voice has the same perceived timbre in a quiet room as at a cocktail party
  - at the party, the set of frequency components arising from that voice is mixed at the listener's ear with frequency components from other sources

Perceptual Constancy

- **Timbre constancy**




"A violin is a violin is a violin"

Psychophysics (circa 1860)

- to derive the mathematical relationship between the **experiential aspect of perception** and the **physical characteristics** of the stimulus


Gustav Fechner

Psychophysical Laws

- **Psychometric Function**
  - formula that relates subjective experience to properties of the physical stimulus
- **Laws: Weber-Fechner, Stevens**
  - variations on mathematical functions that all describe the same relationship

Psychophysical Laws

- **Laws: Weber, Fechner, Stevens**
  - the amount of stimulus needed to notice a change depends on what you already have

Just Noticeable Difference

Weber's Law computes the JND

- the change needed is proportional to the intensity of the stimulus
- JND between two values is directly proportional to the original stimulus value

$$\frac{\Delta I}{I} = k,$$

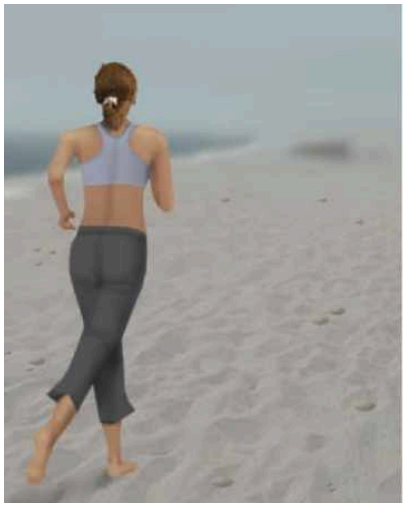
Ernst Heinrich Weber (1795-1878)

1971 1987 1992 2011

Just Noticeable Difference

Helmholtz's theory of unconscious inference (1867)

- our perceptions are the result of *unconscious* assumptions we make about the environment
- includes the likelihood principle



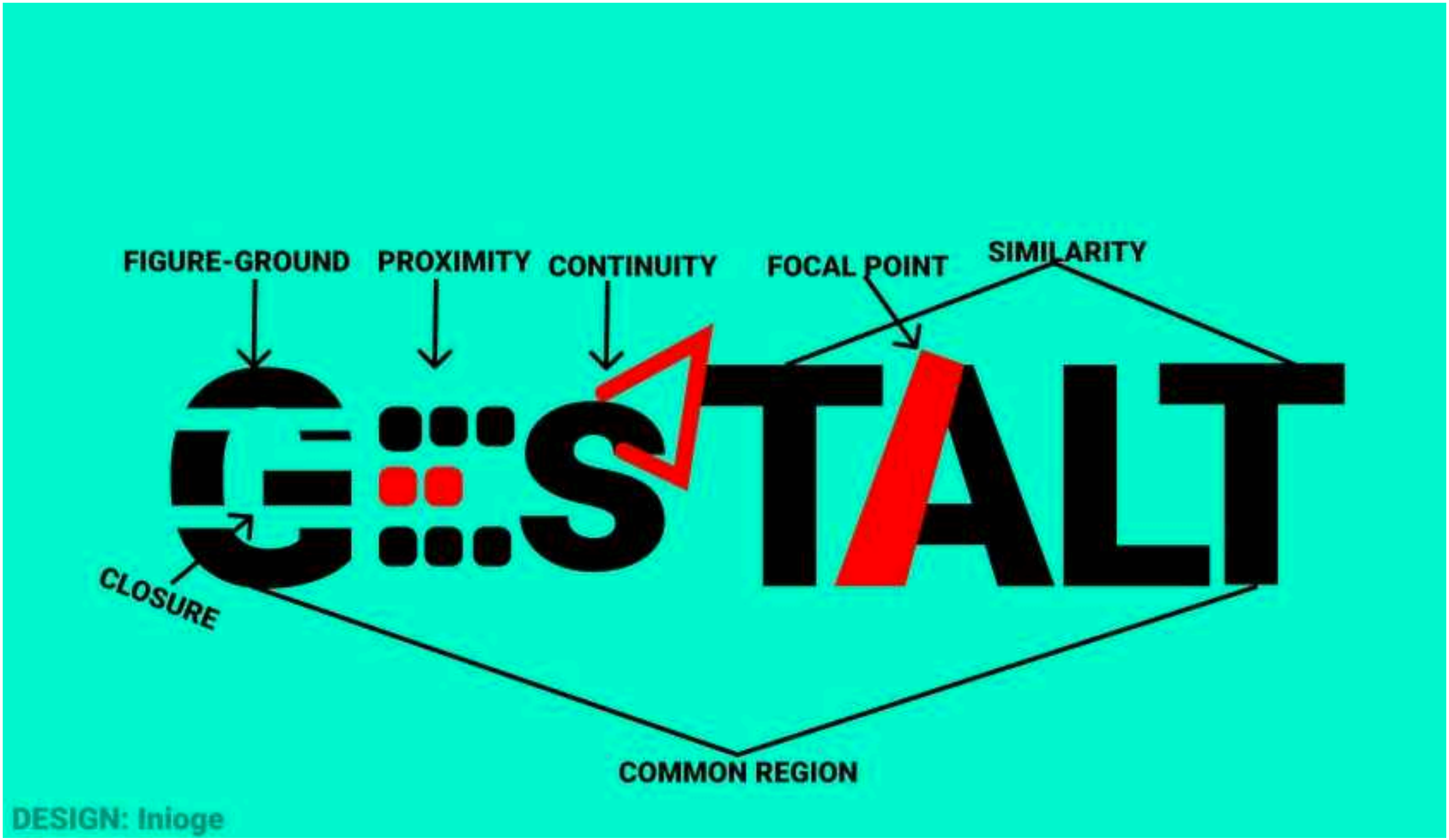


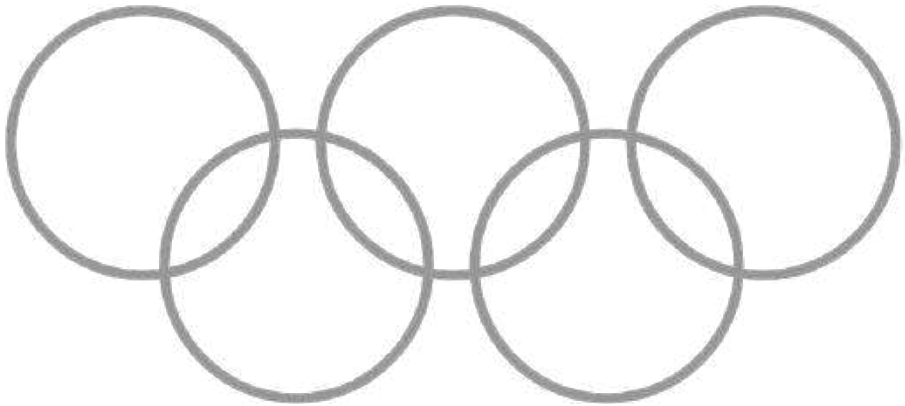
FIGURE-GROUND
PROXIMITY
CONTINUITY
FOCAL POINT
SIMILARITY
GESTALT
CLOSURE
COMMON REGION
DESIGN: Inioge

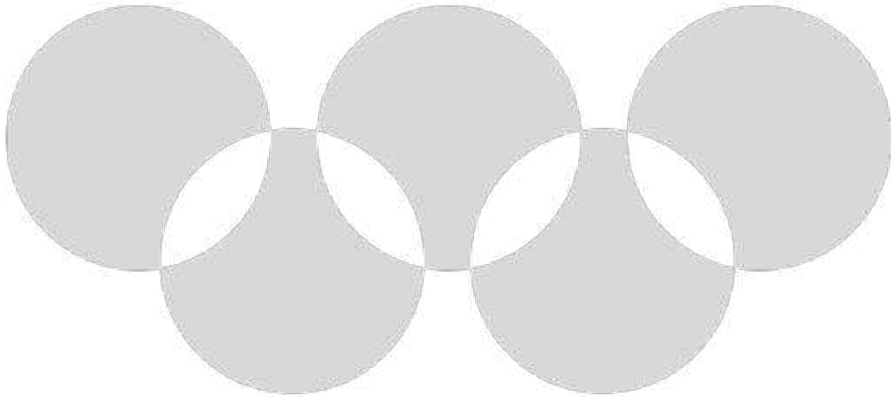
Gestalt Theory (1890)

- Gestalt: shape or form
- started in 1890s
    - Kurt Koffka, Max Wertheimer, Wolfgang Köhler
- reaction to *atomism*
- *atomism*: nature of things is absolute and not dependent on context
- *holistic/gestalt*: **the whole is something else than the sum of its parts**

Gestalt principles of perceptual organization

- brain's innate organising tendencies allow us to perceive things as organised wholes than individual elements
- ***Pragnanz (pithiness/concise)***: perceive and interpret ambiguous or complex images as the **simplest** form(s) possible



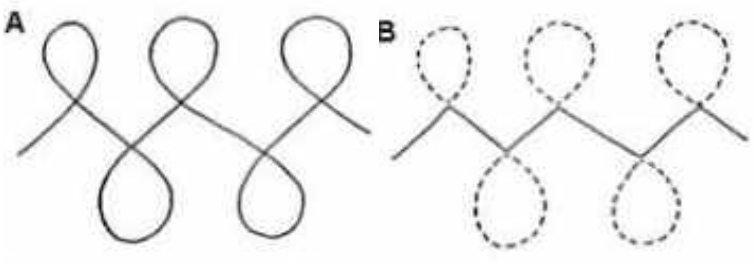


Gestalt principles of perceptual organization

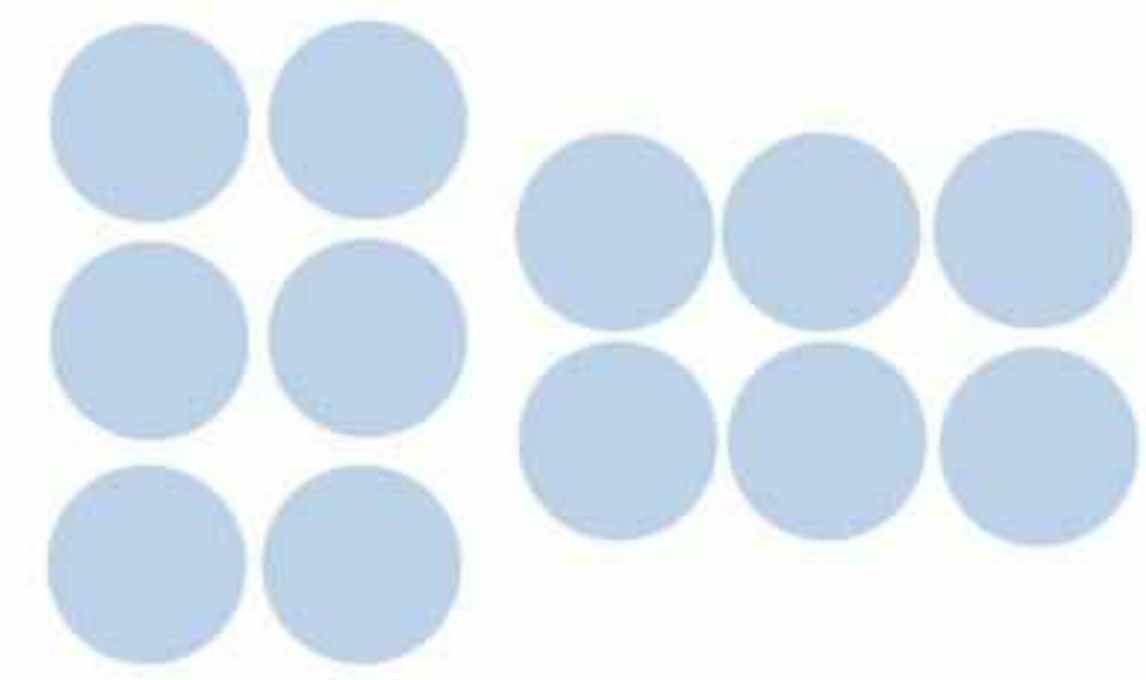
Gestalt principles of perceptual organization

SIMILARITY

Gestalt principles of perceptual organization



Gestalt principles of perceptual organization



Gestalt principles of perceptual organization

Gestalt principles of perceptual organization

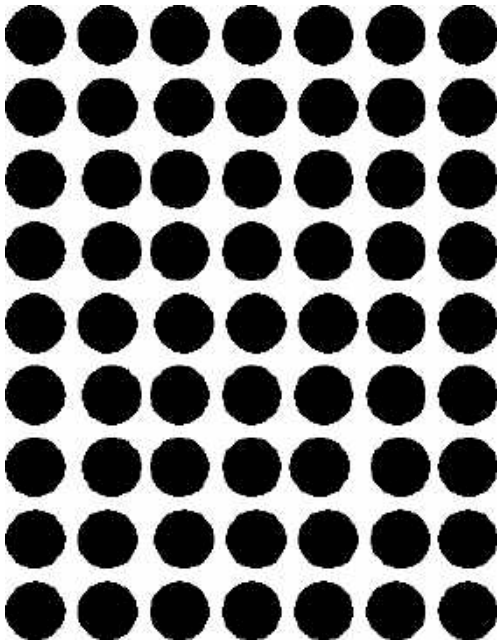
Gestalt principles of perceptual organization

FIGURE-GROUND

Organization depends on what we see as figure (object) and what we perceive as ground (context)

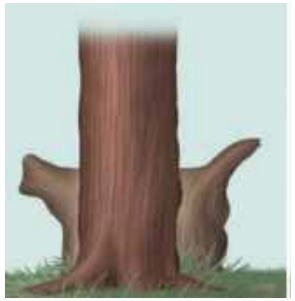
past knowledge

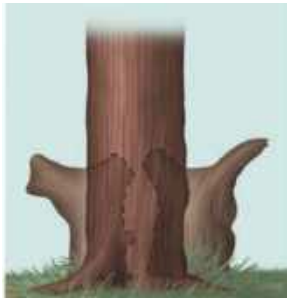
Gestalt principles of perceptual organization



Gestalt laws are **heuristics**

- can lead to incorrect perception or ***error***





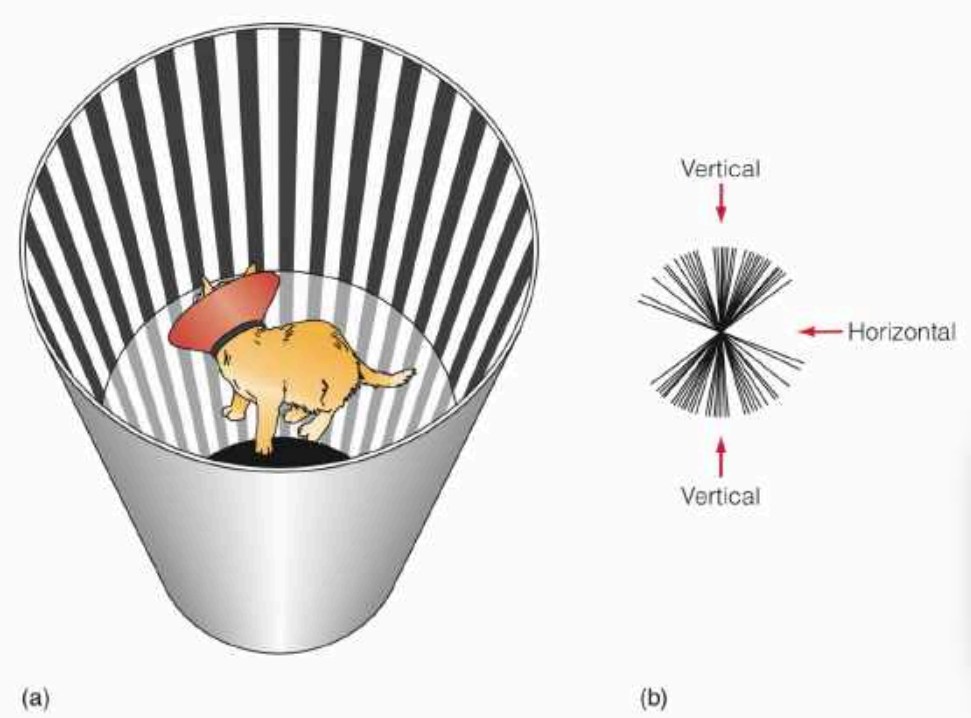
- shaped by knowledge of regularities in the environment

Efficiency in Coding/Representation

Brains, it has recently been argued, are essentially **prediction machines**. They are bundles of cells that support perception and action by constantly attempting to match incoming sensory inputs with top-down expectations or predictions. This is achieved using a hierarchical generative model that aims to minimize prediction error within a bidirectional cascade of cortical processing - **Clark 2013**

Experience-Dependent Plasticity

- learning/experience can shape response properties of neurons



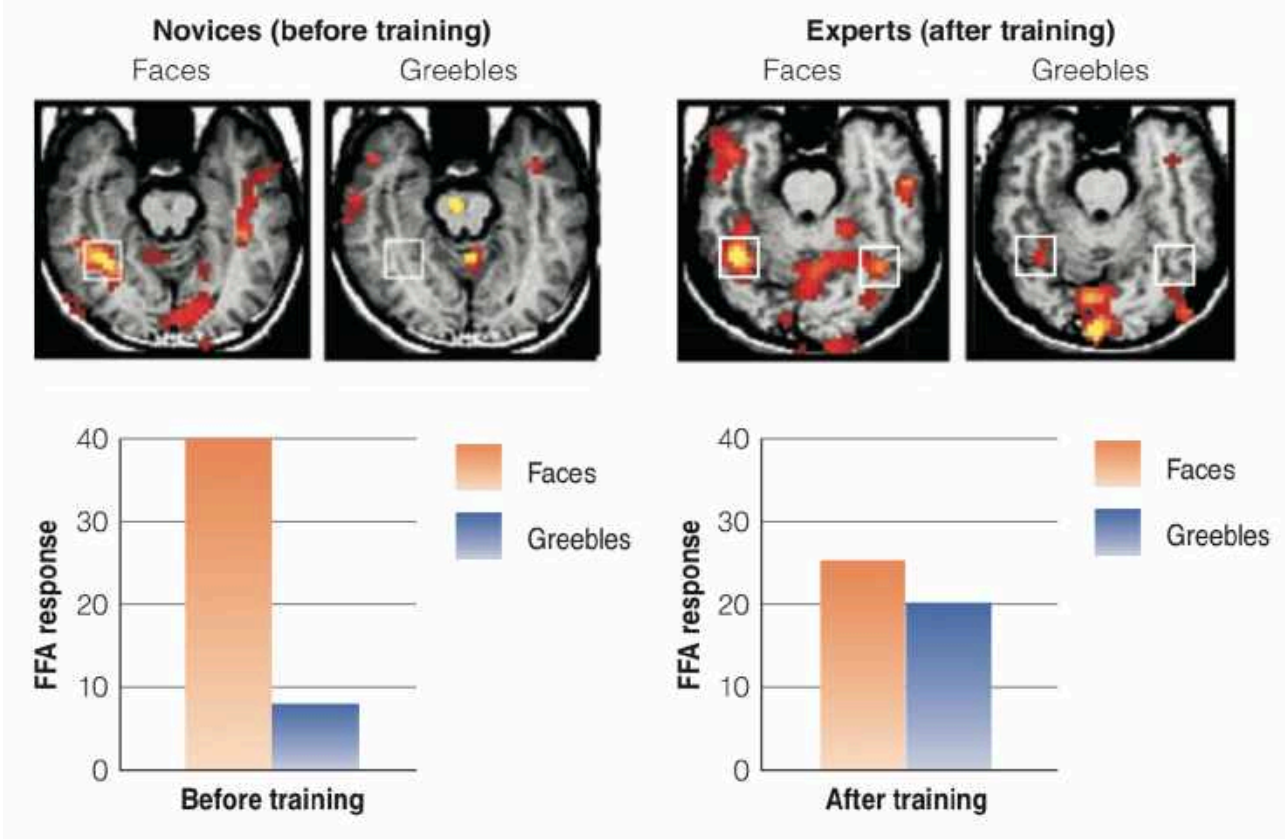
Development of the Brain depends on the Visual Environment

COLIN BLAKEMORE & GRAHAME F. COOPER

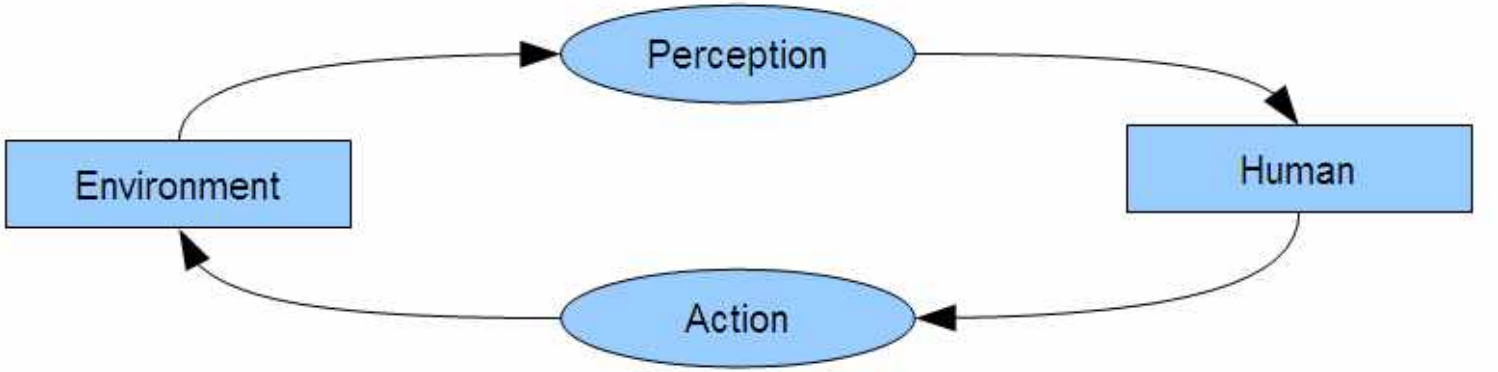
Nature **228**, 477–478 (1970) | Download Citation

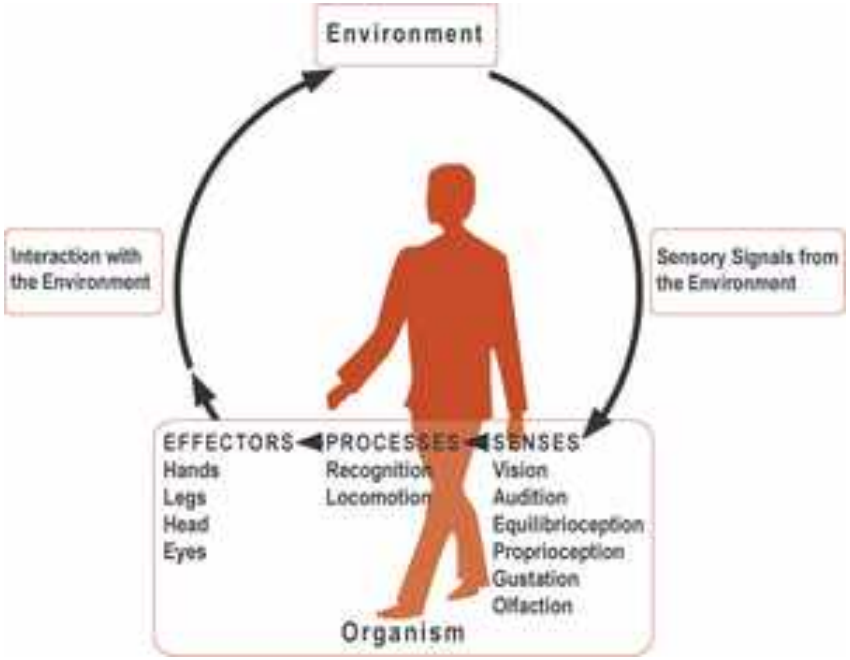
Experience-Dependent Plasticity

● **FIGURE 3.30** Greeble stimuli used by Gauthier. Participants were trained to name each different Greeble. (Source: Reprinted with permissions from I. Gauthier, M. J. Tarr, A. W. Anderson, P. Skudlarski, & J. C. Gore, "Activation of the Middle Fusiform 'Face Area' Increases With Experience in Recognizing Novel Objects," *Nature Neuroscience, 2,* 568–573, 1999.)

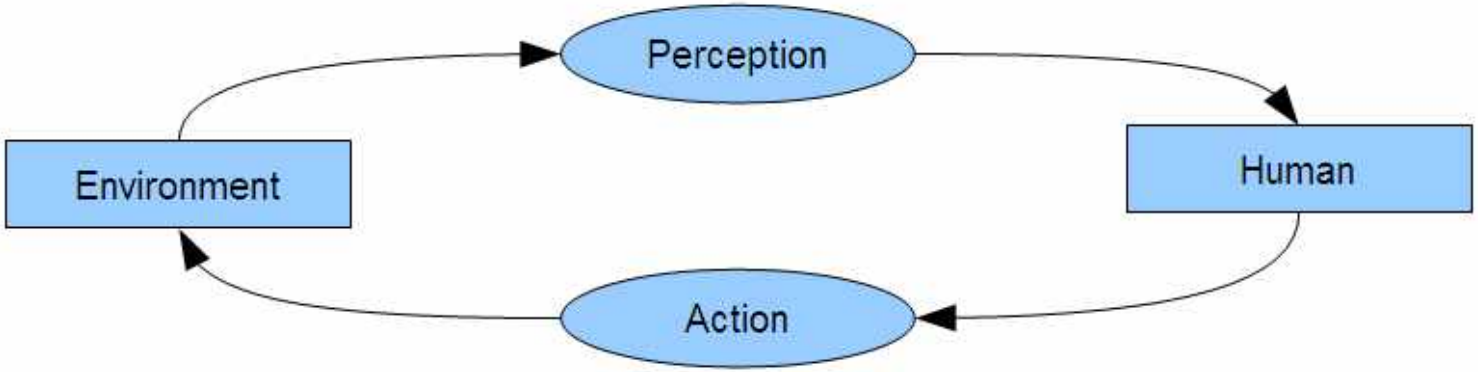


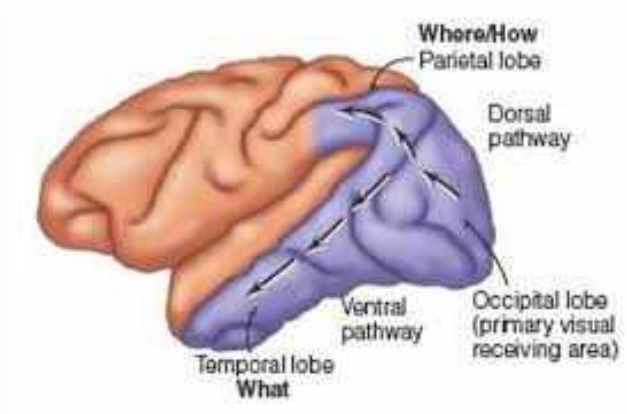
Perception & Action





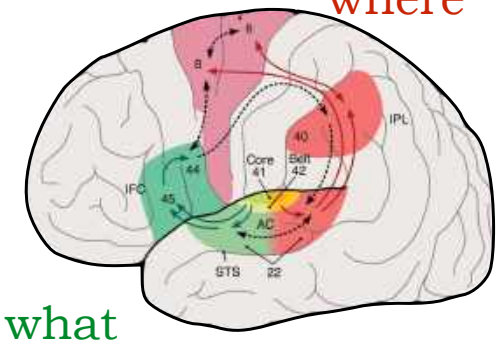
Perception & Action





perception

where

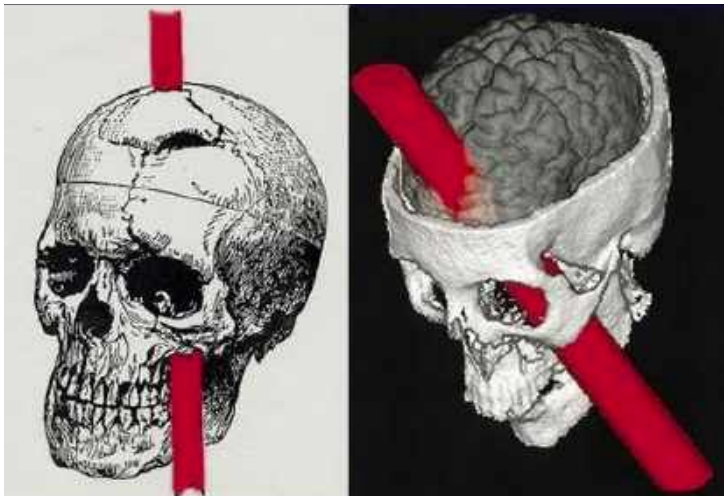


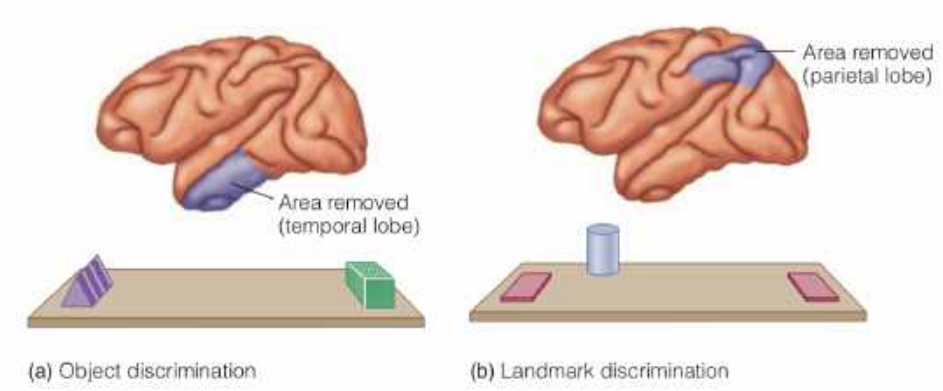
what

action

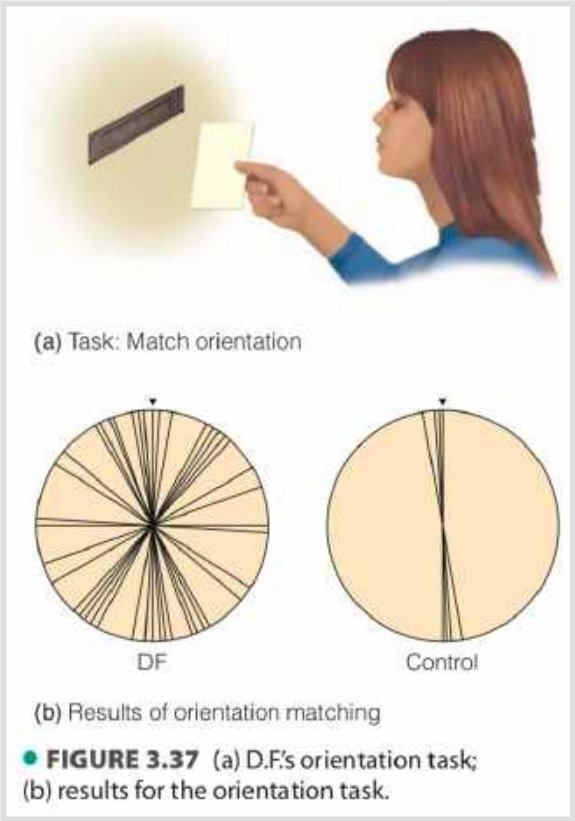
Rauschecker and Scott, 2009

Brain Ablation (animals) vs Human Lesions

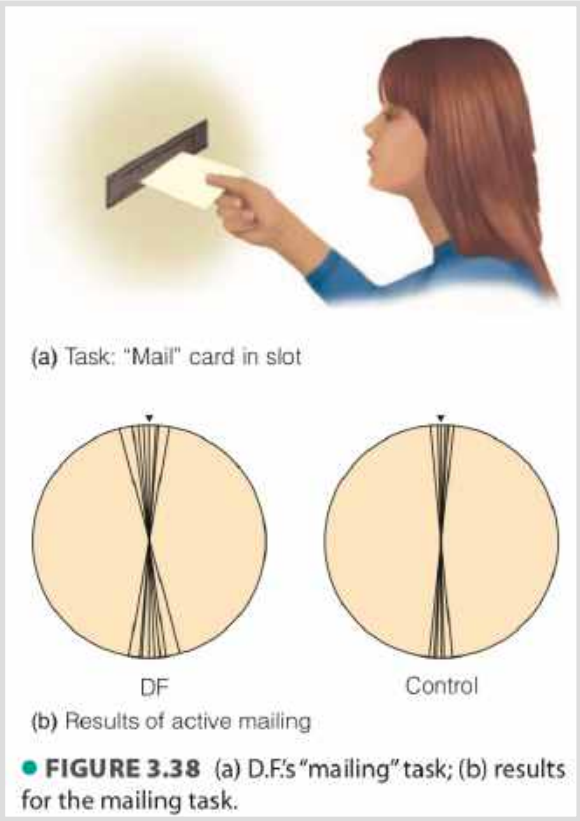




Brain Ablation (animals) vs Human Lesions



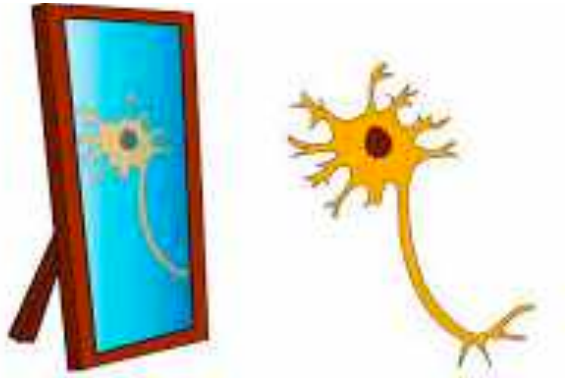
● **FIGURE 3.37** (a) D.F.'s orientation task; (b) results for the orientation task.



● **FIGURE 3.38** (a) D.F.'s "mailing" task; (b) results for the mailing task.


PERCEPTION - ACTION COUPLING


And Antonio's camera assistant
Dominick Dococco.
MakeAGIF.com



perceiving/understanding actions by internally simulating

Mirror Neurons

- first identified by Rizzolati et al. (1996)
- neurons in the premotor cortex respond not just to action but to watching an action

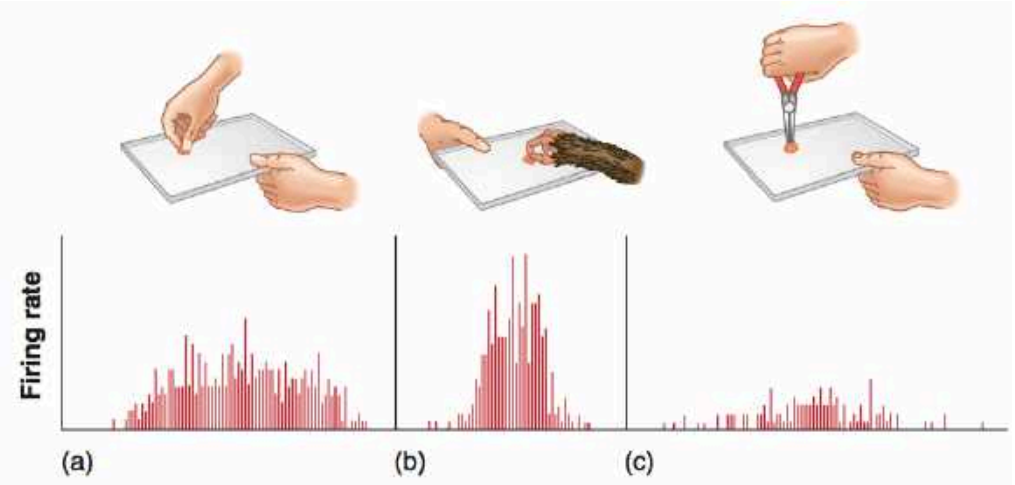


FIGURE 3.40 Response of a mirror neuron when (a) the monkey watches the experimenter grasp food on the tray; (b) the monkey grasps the food; (c) the monkey watches the experimenter pick up food with a pair of pliers.

(Source: Reprinted from G. Rizzolatti et al., "Premotor Cortex and the Recognition of Motor Actions," *Cognitive Brain Research, 3,* 131–141, Copyright © 2000, with permission from Elsevier.)

Mirror Neurons

- *audiovisual mirror neurons* respond also to sounds that are *associated with actions*

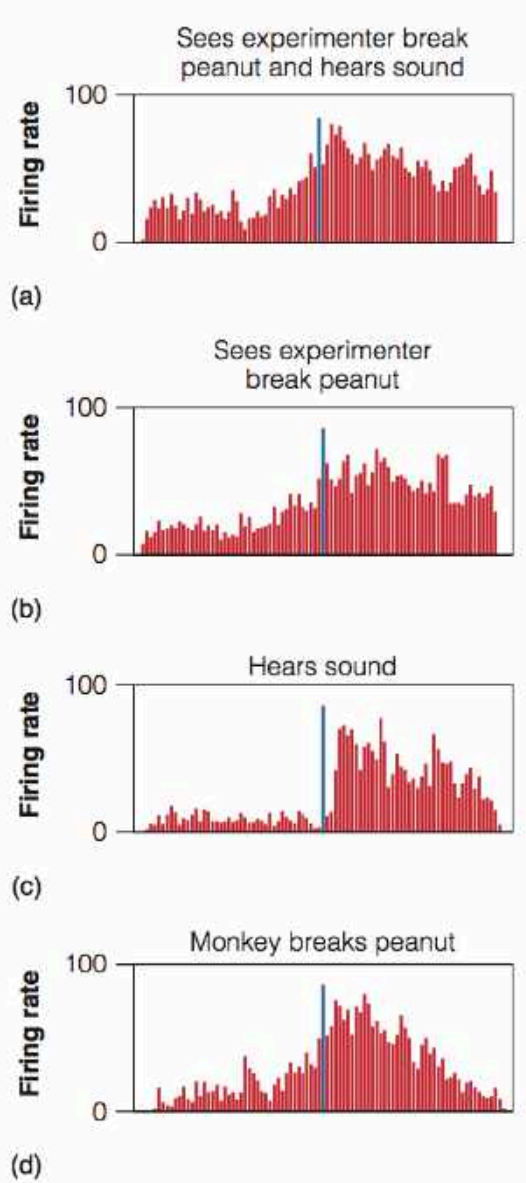
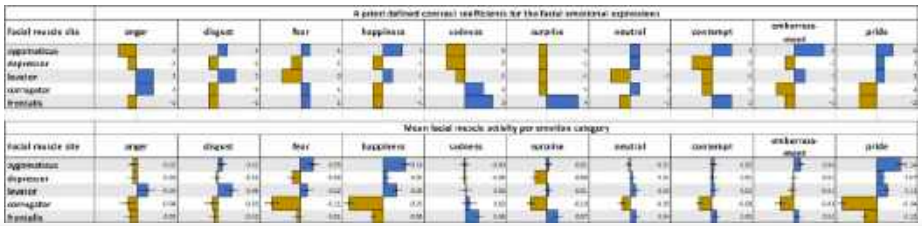


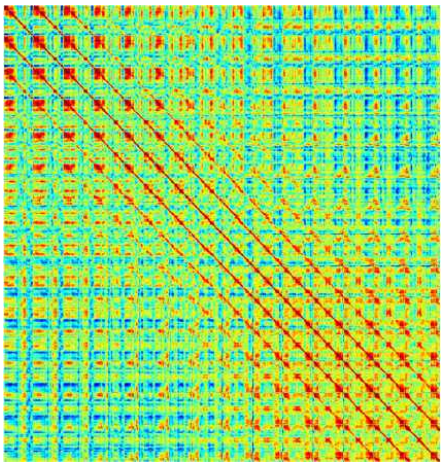
FIGURE 3.41 Response of an audiovisual mirror neuron to four different stimuli. (Source: Kohler et al., 2002.)

	Anger	
Facial muscle site	z-standardised means	expected pattern
zygomaticus	-0.32	-2
depressor	-0.07	-1
levator	0.09	2
corrugator	0.28	2
frontalis	-0.18	-1



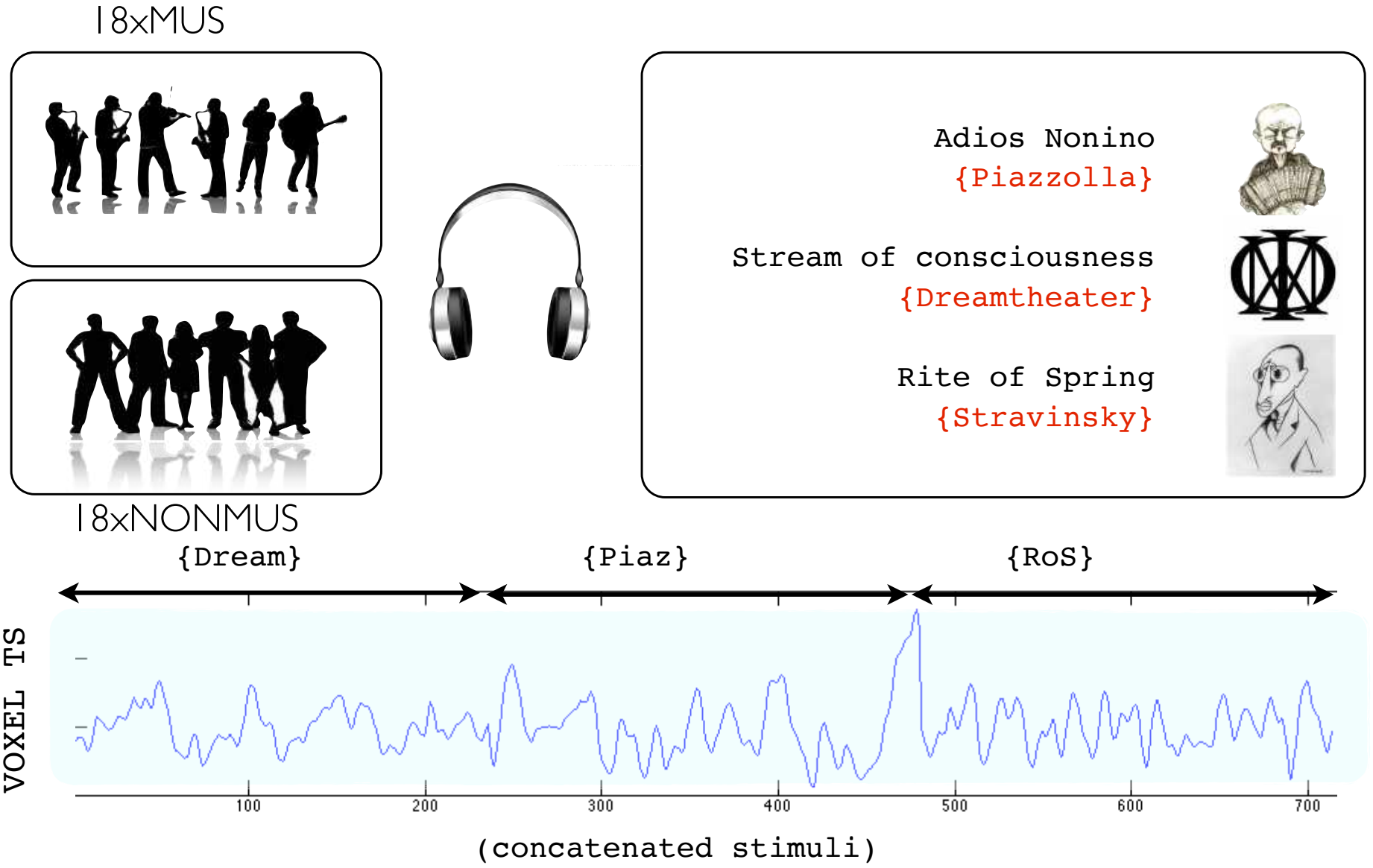
Wingenbach, T.S.H., Brosnan, M., Pfaltz, M.C. *et al.* Perception of Discrete Emotions in Others: Evidence for Distinct Facial Mimicry Patterns. *Sci Rep* **10,** 4692 (2020). https://doi.org/10.1038/s41598-020-61563-5

How do musicians and non-musicians differ in their functional connectivity patterns during continuous music listening?



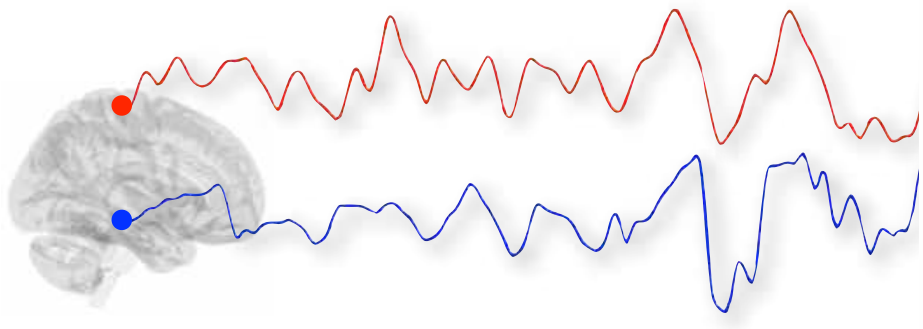
Alluri, V., Toiviainen, P., Burunat, I., Kliuchko, M., Vuust, P., Brattico, E. (2017). Musical Training Modulates Listening Strategies: Evidence for Action-based Processing in Musicians. Human Brain Mapping. doi:10.1002/hbm.23565

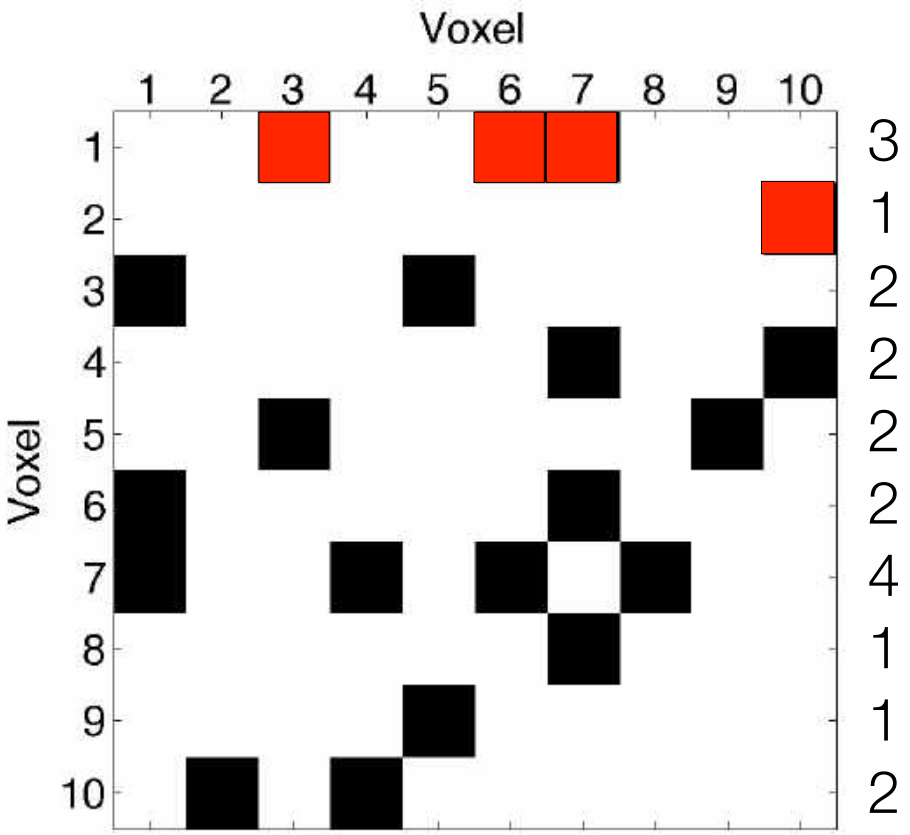
Experimental Setting



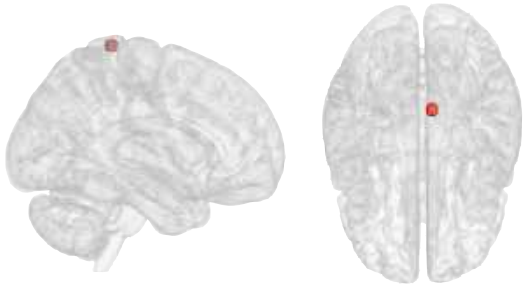
Graph-theoretical analysis

- voxel-by-voxel correlation matrix
- thresholding -> adjacency matrix
- “hubness”/integration measure - *node degree*
- group comparisons





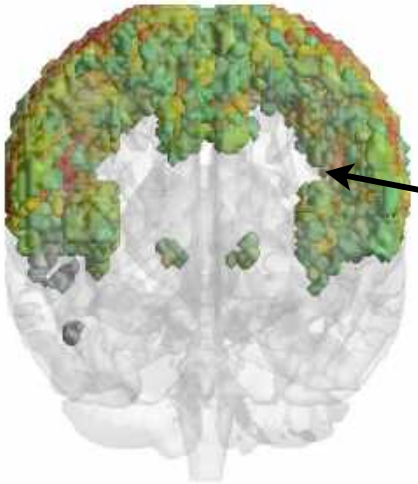
Results | sensorimotor seed



MUS

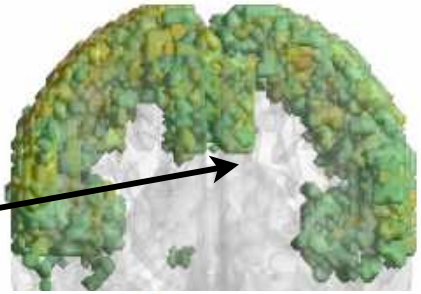
inclusivity per group

NONMUS



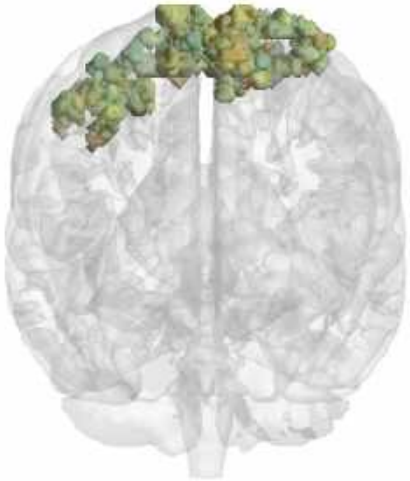
1

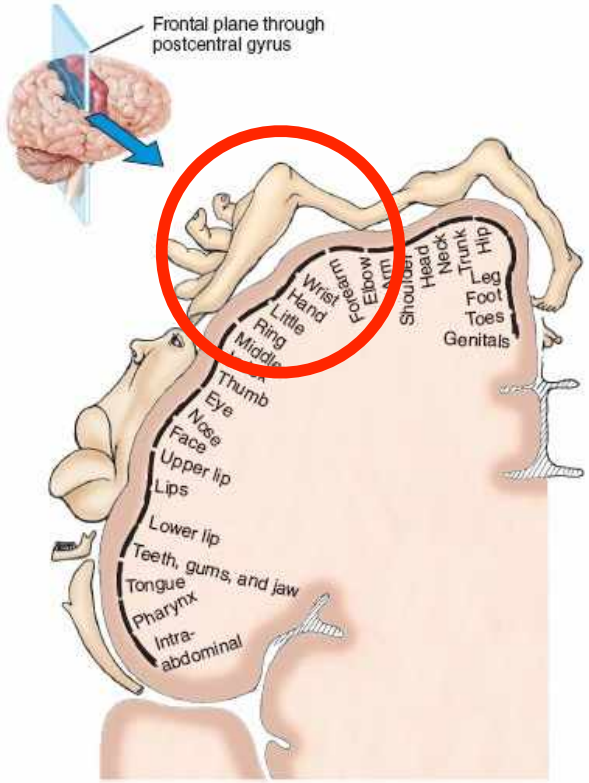
PMC, SMA
somatosensory
auditory



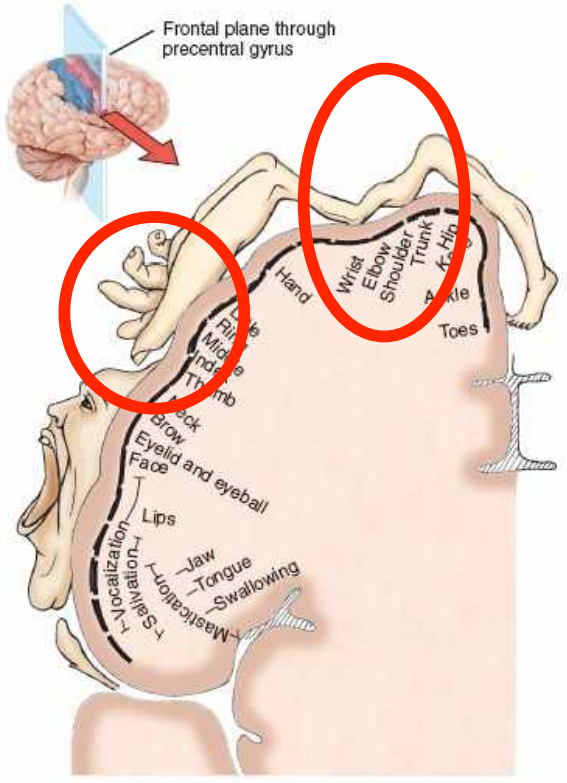
MUS>NONMUS

ir



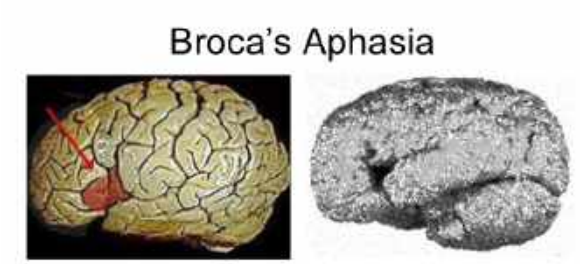


(a) Frontal section of primary somatosensory area in right cerebral hemisphere



(b) Frontal section of primary motor area in right cerebral hemisphere

Mirror Neurons Anomalies



Moebius Syndrome (congenital)
(Inability to generate facial
emotions but can understand)

Mirror Neurons

Perception is grounded in (covert) action

Action is grounded in Perception and not the other way round

— Gregory Hickok