

# Visual Perception

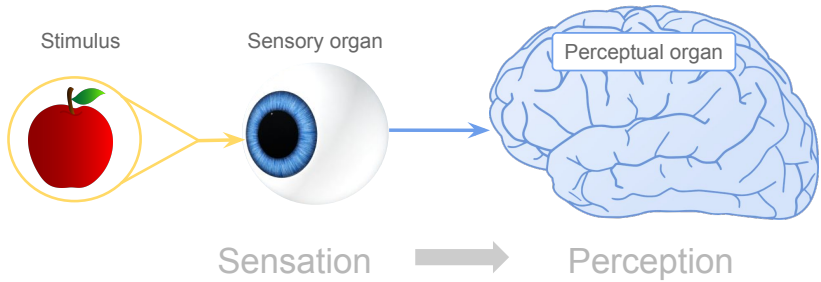
## Intro to Data Visualization

Gaston Sanchez

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# Visual Perception

# Visual Brain



# What is Perception?

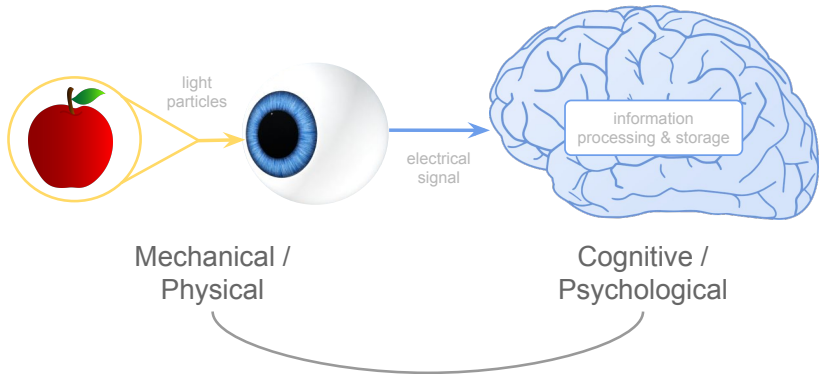
- ▶ It's a cognitive process.
- ▶ Involves interpretation of the world around us.
- ▶ Allows us to form mental representations of the environment.
- ▶ Our brain makes assumptions about the world to overcome the inherent ambiguity in all sensory data.

# Many definitions and theories of perception

Most theories define perception as the process of:

- ▶ **Recognizing** (being aware of) sensory information
- ▶ **Organizing** (gathering and storing) sensory information
- ▶ **Interpreting** (binding to knowledge) sensory information

# Visual Brain



# Brain as a computer

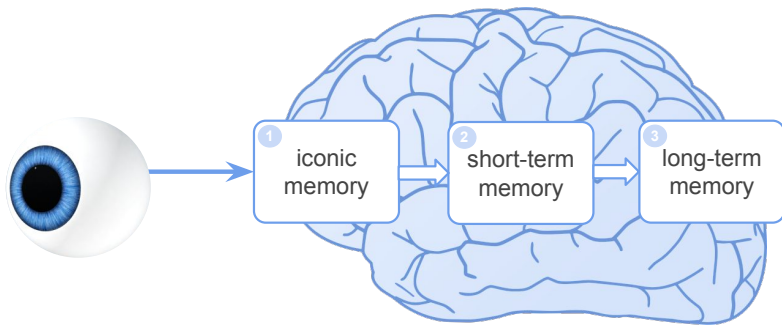
## Brain as a computer

To better understand the process of visual information, it is useful to think about the brain as a computer.

# Attention and Memory



# Information Processing and Memory

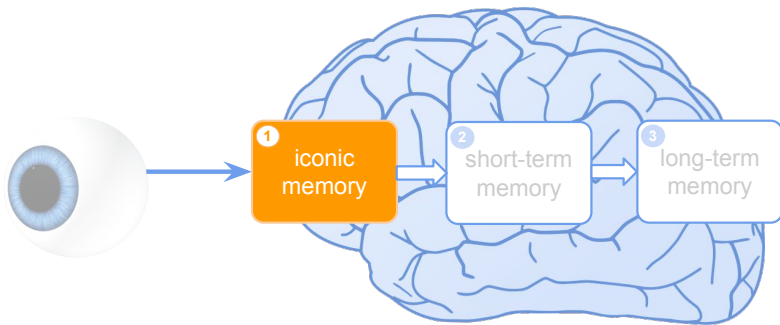


# The brain as a computer

## Types of memory for processing visual information

- ▶ Iconic memory (visual sensory register)  
like the buffer or temporary
- ▶ Short-term memory (working memory)  
like the random access memory (RAM)
- ▶ Long-term memory (“permanent” storage)  
like the hard disk

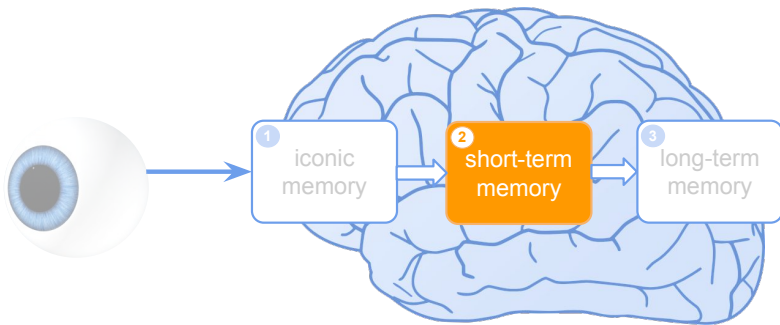
# Iconic Memory



# Iconic Memory

- ▶ The **iconic memory** is a sort of waiting room where each snapshot of input waits to be passed on to short-term memory.
- ▶ Rapid processing: almost automatic and unconscious.
- ▶ Also called **preattentive processing**.
- ▶ Extremely fast and parallel processing.
- ▶ Processes primitive visual features.

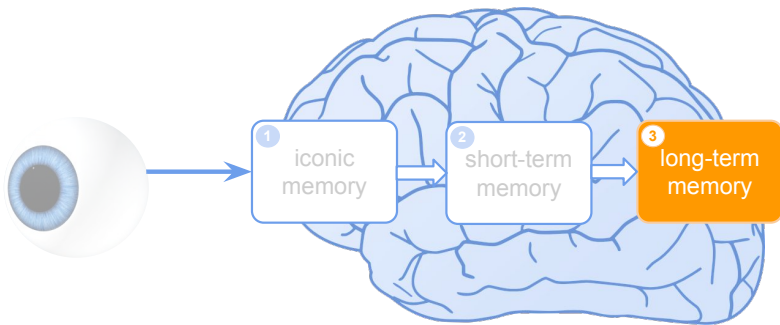
# Short-term Memory



# Short-term Memory

- ▶ The short-term memory is a sort of RAM.
- ▶ This is where conscious mental work is performed to support cognition.
- ▶ Information is combined into meaningful visual chunks.
- ▶ This memory is temporary and has limited storage capacity.
- ▶ Where the attentive process of perception occurs.

# Long-term Memory

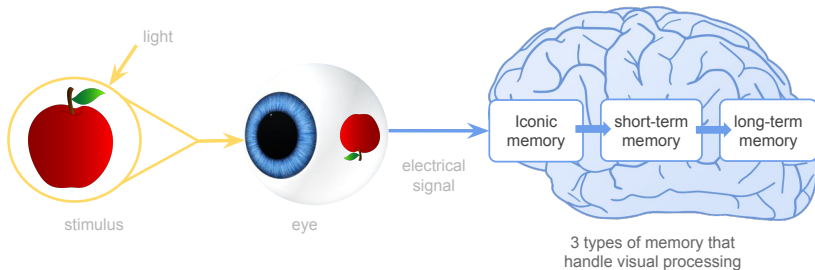


# Long-term Memory

- ▶ The long-term memory is a sort of hard disk.
- ▶ It's a dynamic structure that retains everything we know.
- ▶ Involves an intricate network of links and cross-references that help us find information.
- ▶ Holds our ability to recognize images and detect meaningful patterns.
- ▶ When you selectively pay attention to information in working memory, it is likely to get transformed and encoded into long-term memory.



# Processing Visual Information



### 3 Stages of perceptual processing

- ▶ *Iconic memory*: early, parallel detection of color, texture, shape, and spatial attributes.
- ▶ *Short-term memory*: dividing visual fields into regions and simple patterns.
- ▶ *Working-memory*: holding objects in working memory by demands of active attention.

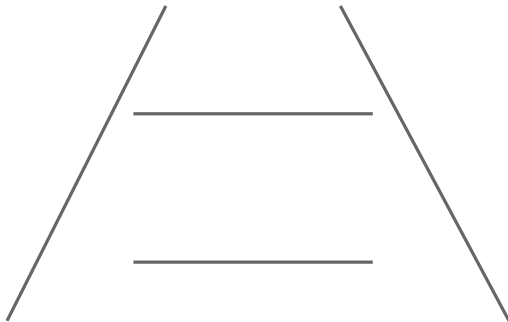
# Illusionss

# Visual Perception and illusions

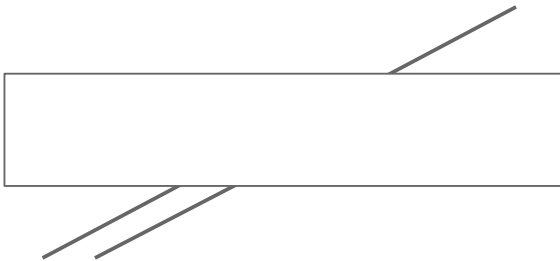
Visual representations of objects are often misinterpreted.

- ▶ Illusions are a primary source of misinterpretations.
- ▶ They come in a variety of forms.
- ▶ Common geometric illusions are:
  - distortions of lengths
  - distortions of angles
  - distortions of areas
  - distortions of shapes

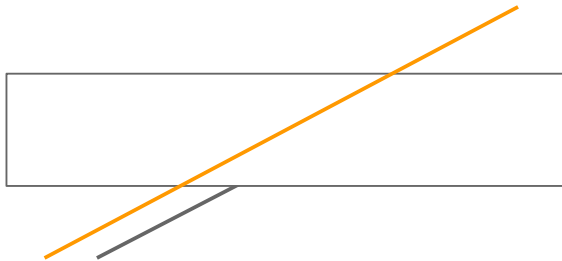
# Ponzo illusion



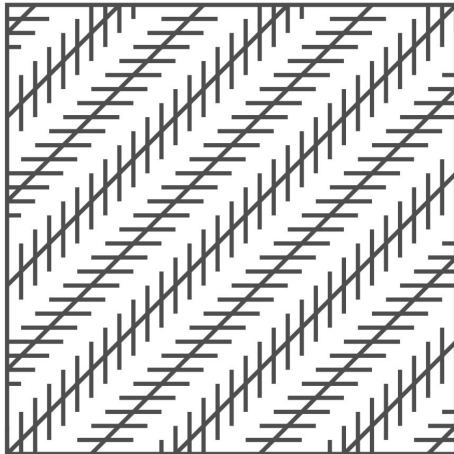
# Poggendorf illusion



# Poggendorf illusion

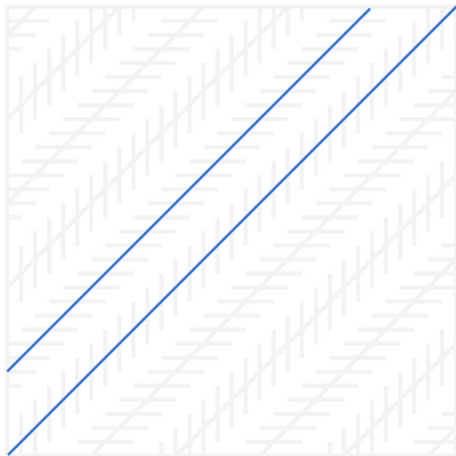


# Zollner illusion

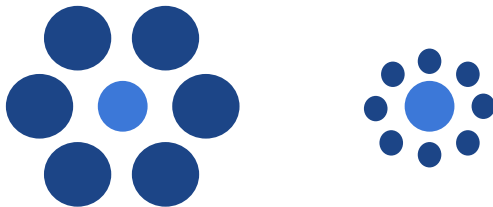




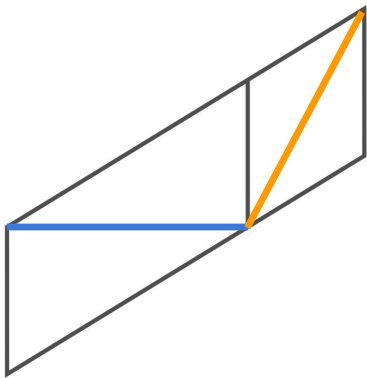
# Zollner illusion



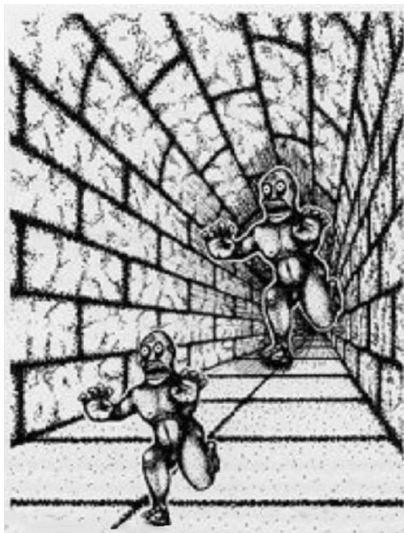
# Tichener illusion



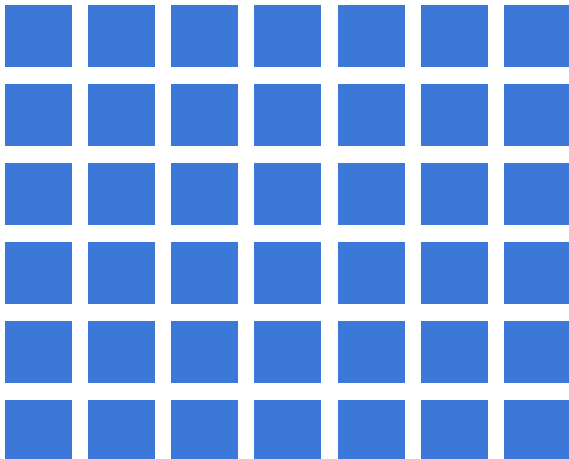
# A Line Length illusion



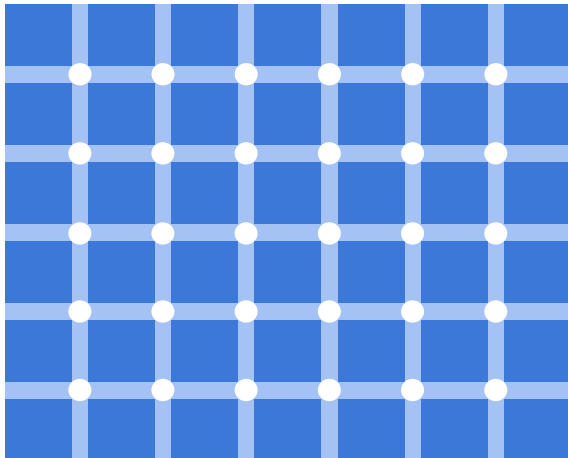
# Perspective illusion



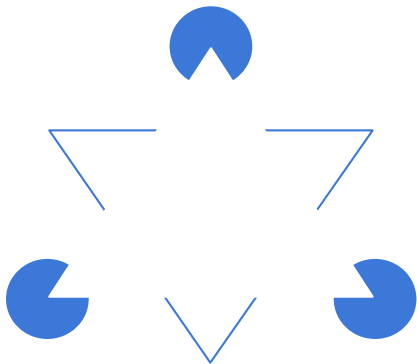
# The Herman Grid



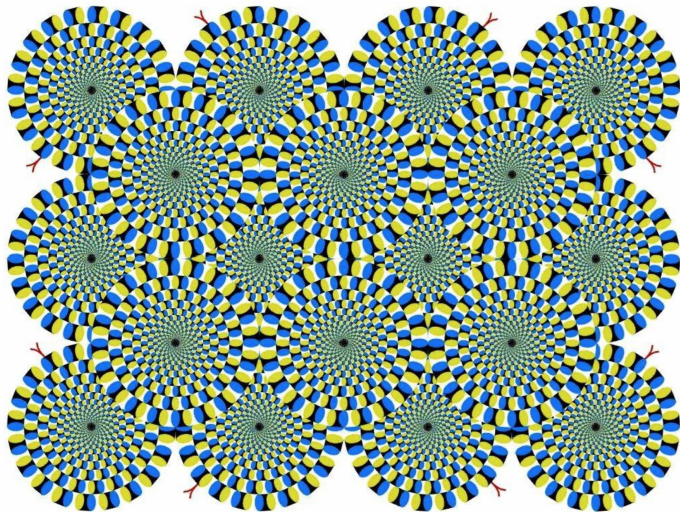
# The Herman Grid



# Kanizsa illusion

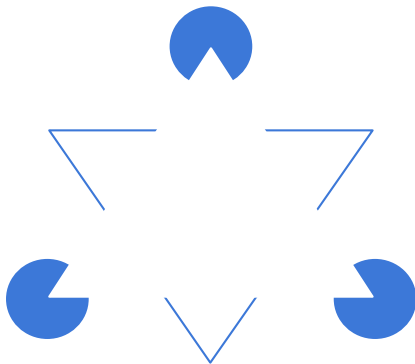


## More illusions





# Kanizsa Illusion



# Perceptual Processing

# Perceptual Processing

- ▶ Classic model of information processing
- ▶ Simple model for understanding the flow of sensory information
- ▶ Processing divided into preattentive and postattentive

# Preattentive Processing

## About Preattentive Processing

Researchers have discovered a limited set of individual properties that are detected very rapidly and accurately by the low-level visual system. These properties were initially called *preattentive*. We now know that attention plays a critical role in what we see. The term *preattentive* continues to be used. Preattentive tasks are those performed in less than 200 to 250 milliseconds.

# Early Vision -vs- Later Vision

## Early Vision



Iconic Memory



Preattentive  
Processing



Parallel & Rapid

## Later Vision



Short-term Memory



Postattentive  
Processing



Serial & Slow

# Early Vision and Preattentive Processing

# Stage 1: Low-level Preattentive Processing

- ▶ Arrays of neurons work in parallel
- ▶ Requires attention despite the name
- ▶ Occurs almost automatically (very fast:  $< 200\text{-}250$  ms)
- ▶ Information is transitory, briefly held in iconic store
- ▶ What matters most is the contrast between features

# Preattentive Processing

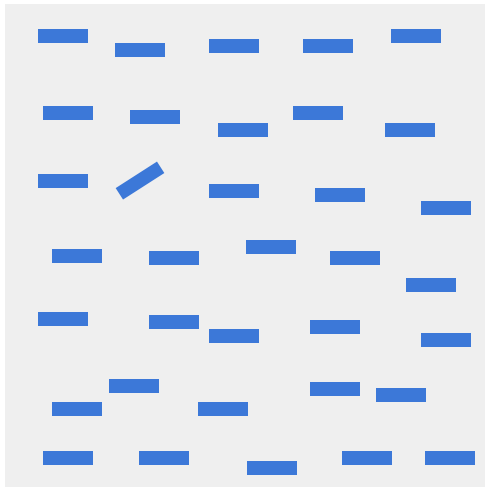
## Preattentive Features

Visual features have been identified as preattentive in various experiments in psychology to perform 4 major visual tasks:

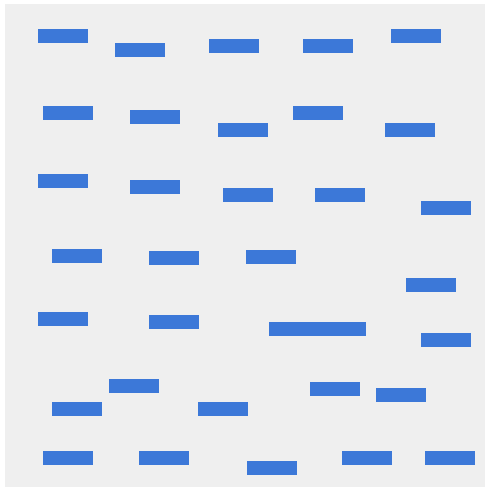
- ▶ target detection
- ▶ boundary detection
- ▶ region tracking
- ▶ counting and estimation



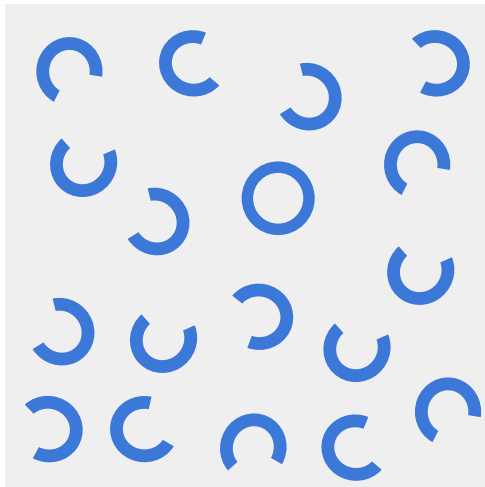
# Orientation



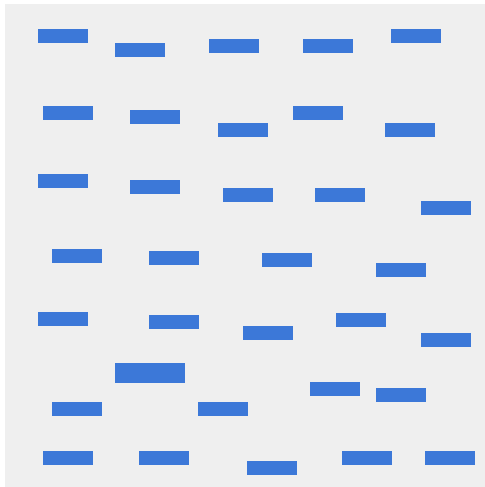
# Length-Width



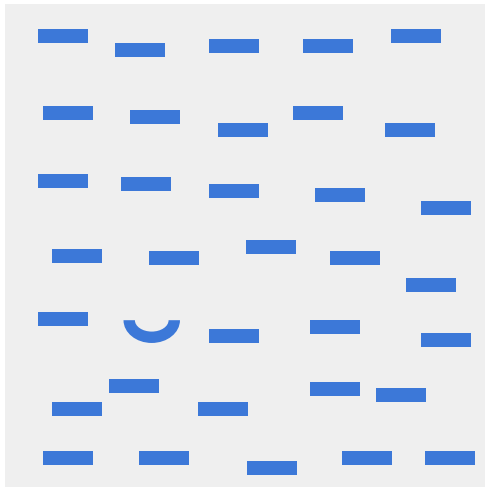
# Closure



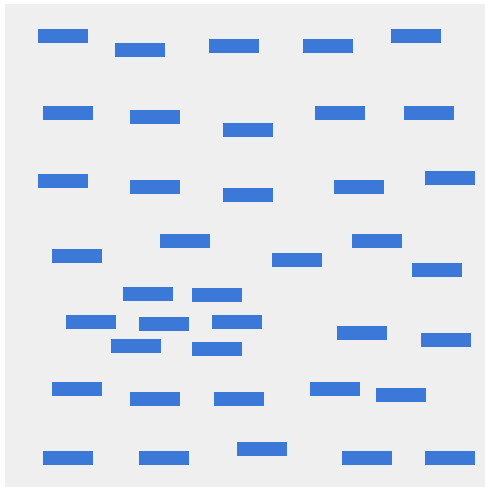
# Size



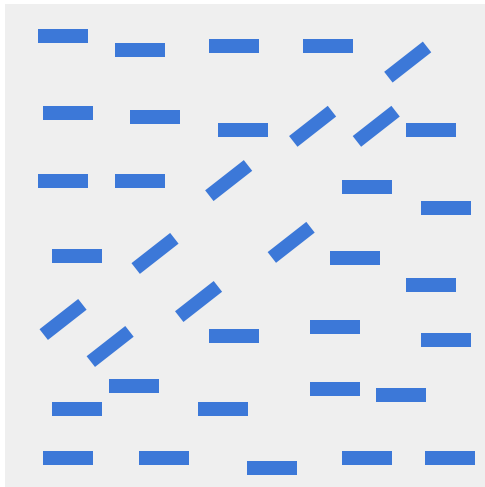
# Curvature



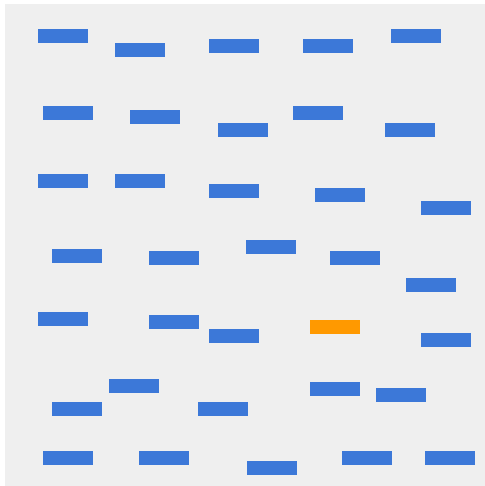
# Density



# Number Estimation

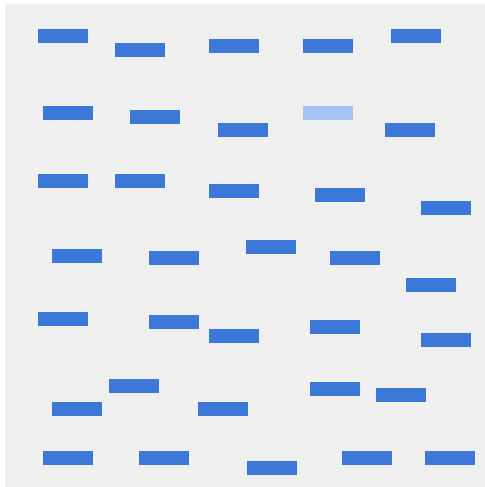


# Number Color (hue)

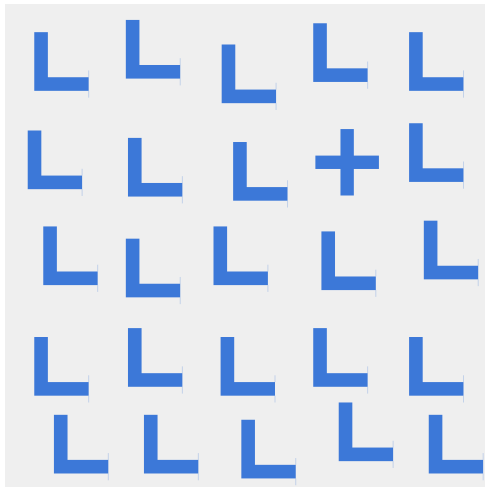




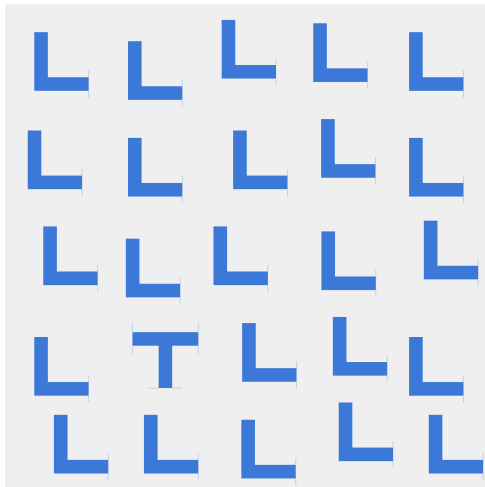
# Intensity



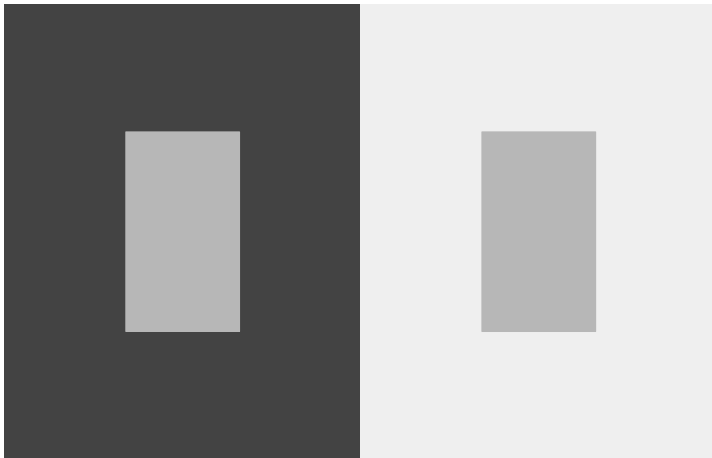
# Intersection



# Terminators



# Simultaneous contrast



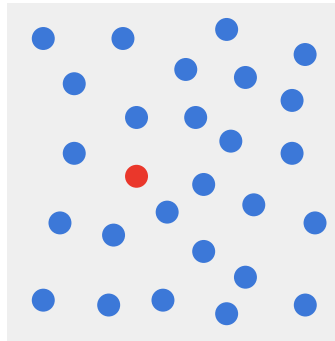
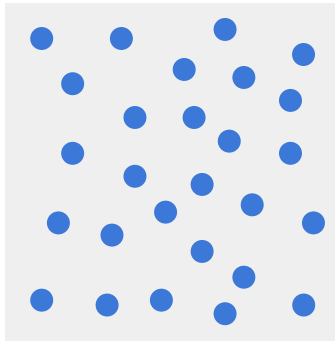
How many 5s?

1 5 0 2 2 9 5 1 9 4 2 4 2 1 6 2 9 1 1 3 6 8 5 0 2 8  
9 1 4 6 5 0 7 4 3 0 1 7 0 4 9 9 7 7 6 2 2 4 8 6 7 4  
6 4 0 9 4 0 8 3 5 1 8 6 9 2 8 3 9 8 4 1 0 7 8 9 6 0  
7 0 8 2 8 5 4 3 2 1 8 7 7 4 6 3 8 3 8 2 0 4 1 0 2 3

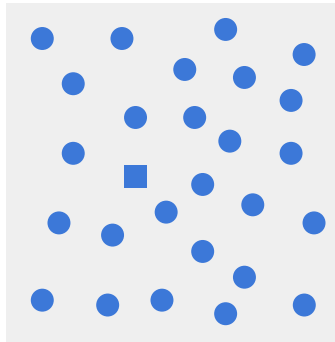
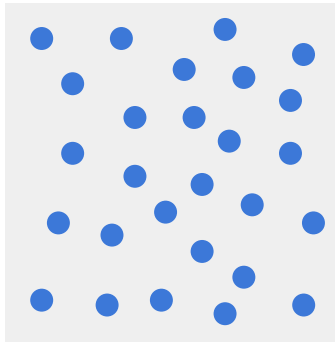
# How many 5s?

1 5 0 2 2 9 5 1 9 4 2 4 2 1 6 2 9 1 1 3 6 8 5 0 2 8  
9 1 4 6 5 0 7 4 3 0 1 7 0 4 9 9 7 7 6 2 2 4 8 6 7 4  
6 4 0 9 4 0 8 3 5 1 8 6 9 2 8 3 9 8 4 1 0 7 8 9 6 0  
7 0 8 2 8 5 4 3 2 1 8 7 7 4 6 3 8 3 8 2 0 4 1 0 2 3

# Color

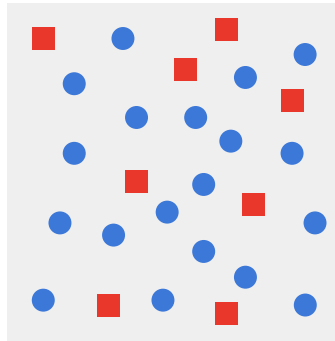
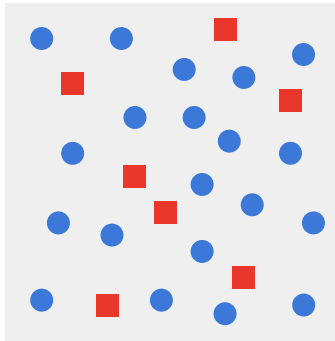


# Shape





# Conjunction



# Theories of Preattentive Processing

- ▶ “Feature Integration Theory” by Anne Treisman.
- ▶ “Texton Theory” by Bela Julesz.
- ▶ “Similarity” Theory by Quinland and Humphreys.
- ▶ “Guided Search” Theory by Jeremy Wolfe.
- ▶ “Boolean Map” Theory by Huang et al.

# Later Vision and Postattentive Processing

# Postattentive Processing

## Preattentive processing asks in part:

“What visual properties draw our eyes, and therefore our focus of attention” .

## Postattentive processing asks:

“What happens to the visual representation of an object when we stop attending to it (and look at something else)?”

# Later Vision: Pattern Perception

- ▶ Slow serial processing
- ▶ Involves working and long-term memory
- ▶ A combination of bottom-up feature processing and top-down attentional mechanisms
- ▶ Different pathways for object recognition and visually guided motion

# Ron Rensink's examples



# Ron Rensink's examples



# Ron Rensink's examples





# References

- ▶ **Perception in Visualization** by Christopher Healey.
- ▶ **The Functional Art** (chapter 6) by Alberto Cairo.
- ▶ **Visual Language for Designers** (principle 1) by Connie Malamed.
- ▶ **Information Dashboard Design** (chapter 4) by Stephen Few.
- ▶ **Interactive Data Visualization** (chapter 3) by Ward, Grinstein and Keim.
- ▶ **100 Things Every Designer Needs to Know About People** (chapter 1) by Susan M. Weinschenk.