MDS651
UNIT 1 - INTRODUCTION

Dipesh Koirala

OUTLINE

- Introduction of Visual Perception
- Visual Representation of Data
- Data Abstraction
- Visual Encodings
- Use of Color
- Perceptual Issues
- Information Overloads

LET'S BEGIN FROM HERE

What is data?

- Collection of records and their attributes
- An attribute is a characteristic of an object
- A collection of attributes describe an object

Attributes

Objects

Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	125K	No
2	No	Married	100K	No
3	No	Single	70K	No
4	Yes	Married	120K	No
5	No	Divorced	95K	Yes
6	No	Married	60K	No
7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes

LET'S BEGIN FROM HERE

Data comes from everywhere

But, they have different form

Hospital

Weather Station

Social Media

LET'S BEGIN FROM HERE

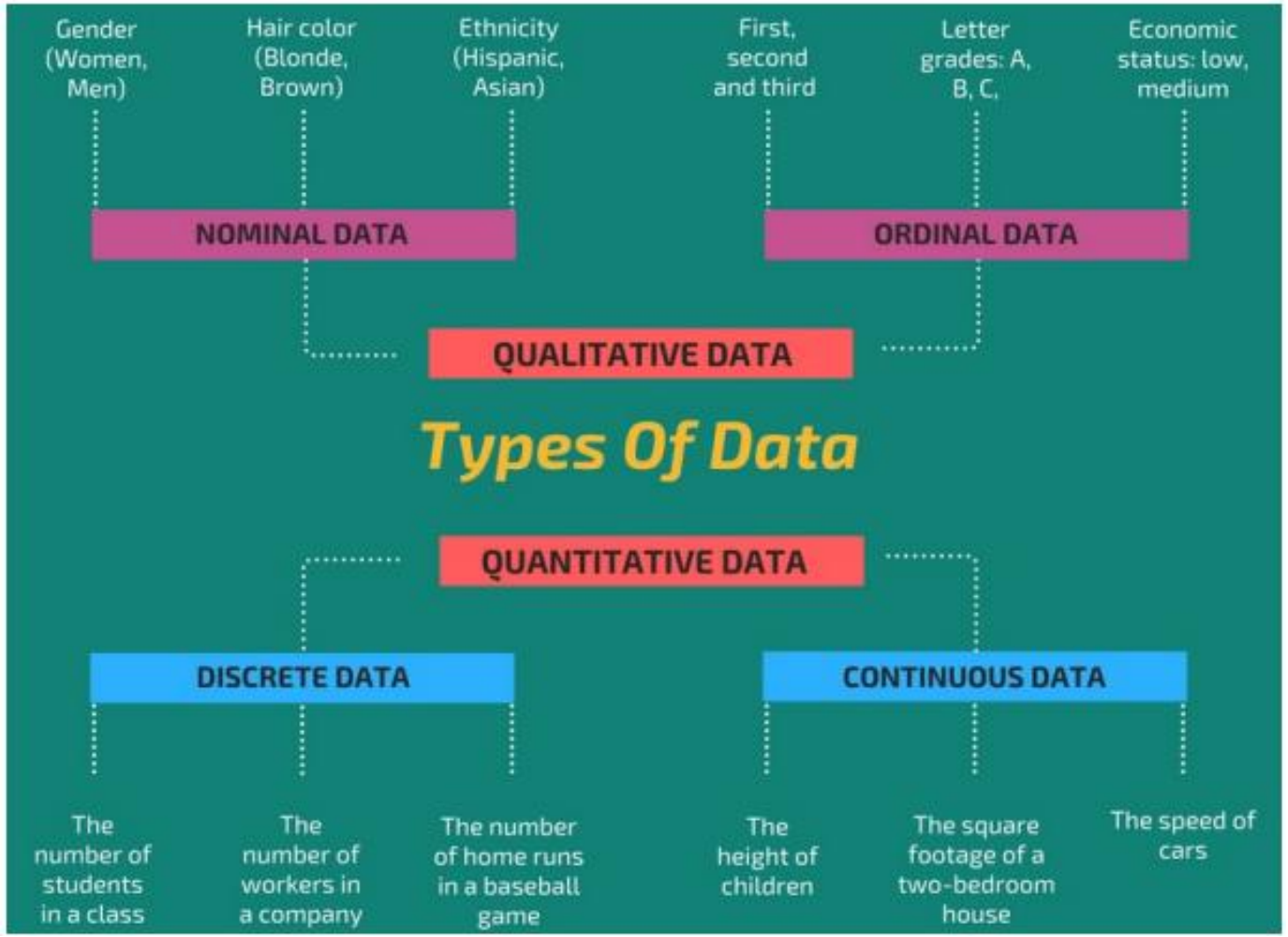
Types of Source of Data

- Record Data
  - Transactional Data
- Temporal Data
  - Time Series Data
  - Sequence Data
- Spatial & Spatial-Temporal Data
  - Spatial Data
  - Spatial-Temporal Data

- Graph Data
  - Transactional Data
- UnStructured Data
  - Twitter Status Message
  - Review, news article
- Semi-Structured Data
  - Paper Publications Data
  - XML format

LET'S BEGIN FROM HERE

Types



DATA VISUALIZATION

- **Visualization** is the communication of information using graphical representations.
- A single picture can contain a wealth of information, and can be processed much more quickly than a comparable page of words.

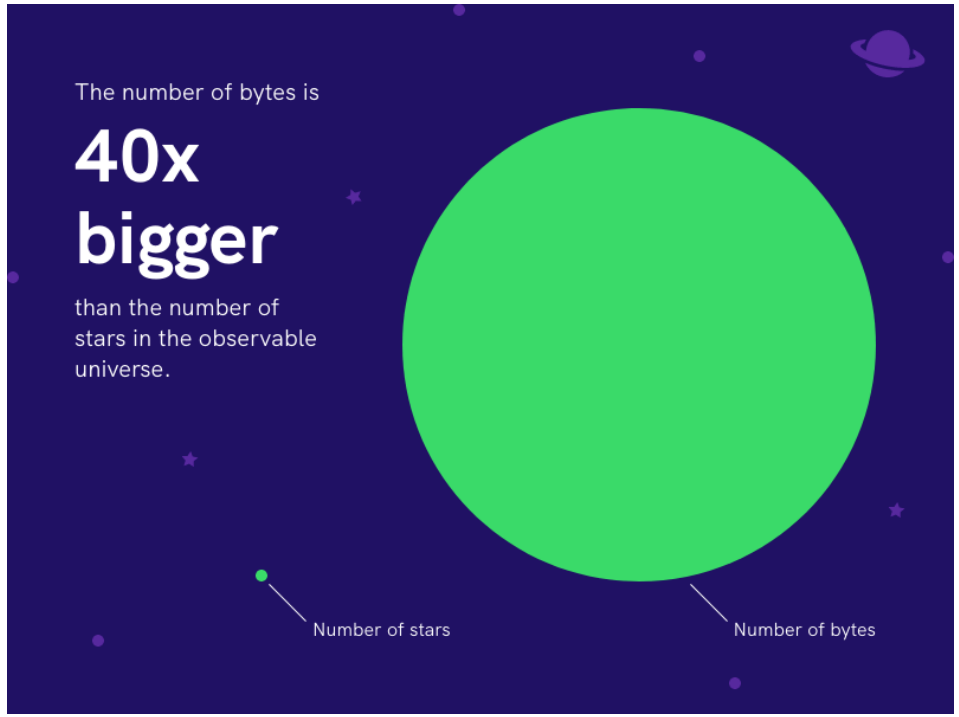
Some stats:

- The human brain can process an image in just **13 milliseconds** (Source: MIT)
- Human brains process visuals **60, 000 times faster** than they do text. (Source: University of Minnesota)

CONTINUE

Capture this

Facebook users post around 350 million photos in a day, which contributes 4 petabytes of data. (Raconteur). To help you grasp the magnitude of this number, the Milky Way Galaxy is home to approximately 200 billion stars. Assuming every individual star was a single byte, we would need 20,000 Milky Way Galaxies to match the number of stars with the number of data created by Facebook users each day.



Source: https://piktochart.com/blog/data-visualization-statistics/

No of bytes daily in facebook > Stars in Milky Way Galaxy

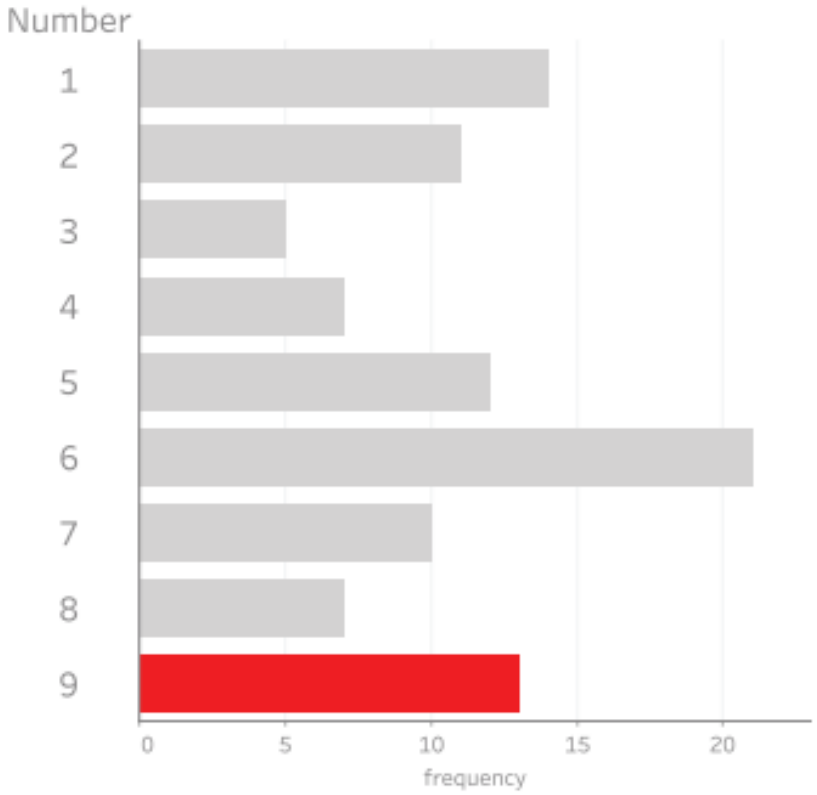
CONTINUE

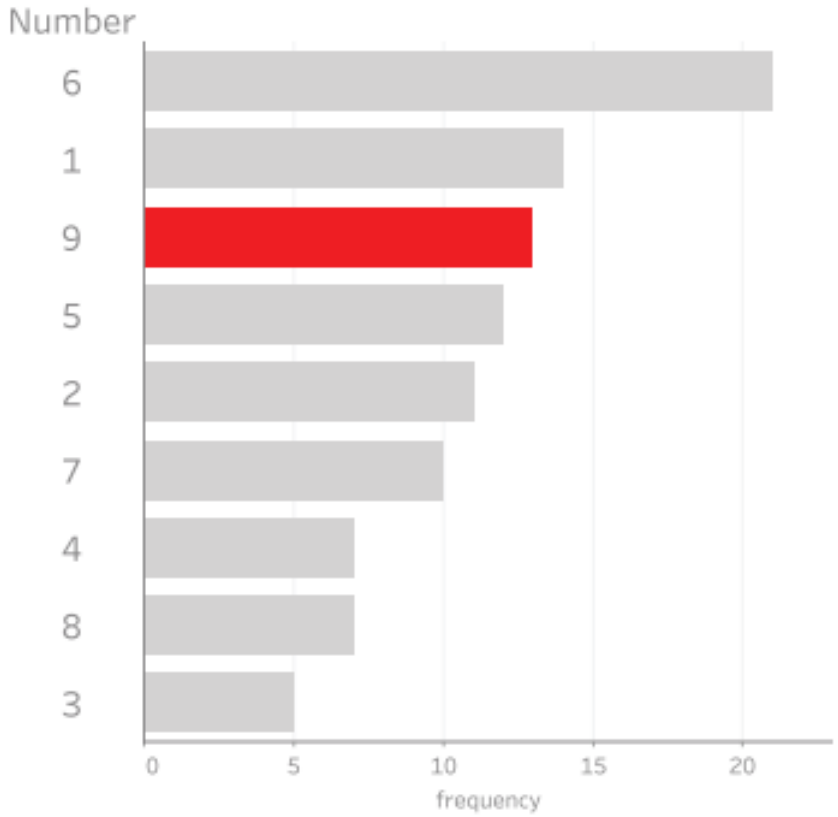
Why do we need data visualization?

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

CONTINUE

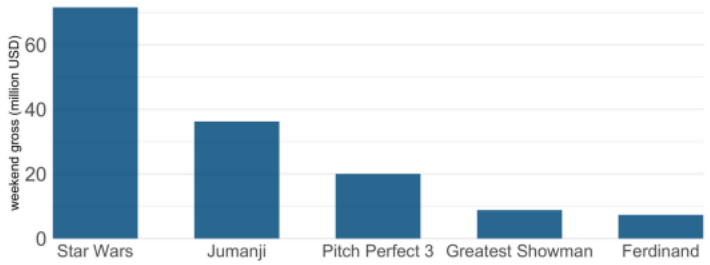
Why do we need data visualization?

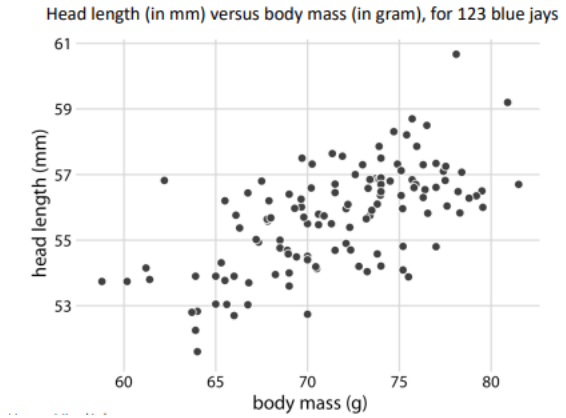


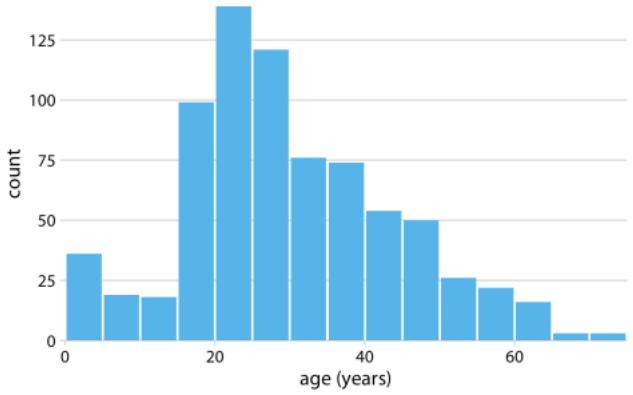


CONTINUE

- Data visualization is the creation and study of the **visual representation of data**
- Turning numbers and text into pictures (charts, graphs, maps, dashboards) to tell story, identify patterns, trends and insights that might be hidden in raw numeric data
- Presenting complex datasets in a way that is easy to understand an interpret







CONTINUE

What makes an effective data visualization?

- It has clear purpose and message

  Complements and enhances the text

- It is easy to interpret

  Note: A good figure is like a joke, if you have to explain it, it's not that good.

- It accurately reflects the data.

CONTINUE

Benefits:

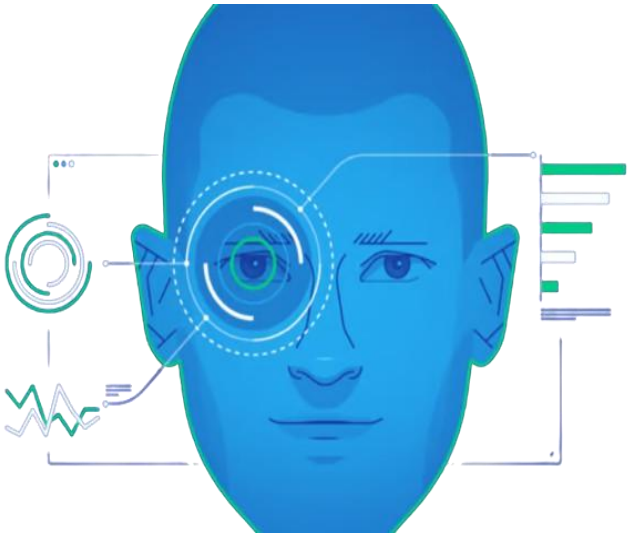
- Simplify Complexity : Make large or intricate datasets digestible and less intimidating.
- Identify patterns and trends : Easily spot relationships, correlations, and shifts over time.
- Reveal Insights : Uncover hidden information that might not be obvious in tables.
- Communicate Effectively : Convey findings and conclusions to various audiences, including non-technical stakeholders.
- Support Decision-Making: Provide a clear basis for informed actions and strategies.

INTRODUCTION TO VISUAL PERCEPTION

- Visual perception is the process by which our brains receive, organize, and interpret visual stimuli presented in visual representations of data or environment.

- It involves a complex interplay between the physical properties of light and the neural mechanisms that process this information in the brain.

- It's about leveraging the innate capabilities of human vision to ensure that the data is not just seen, but *understood* quickly and accurately.



INTRODUCTION TO VISUAL PERCEPTION

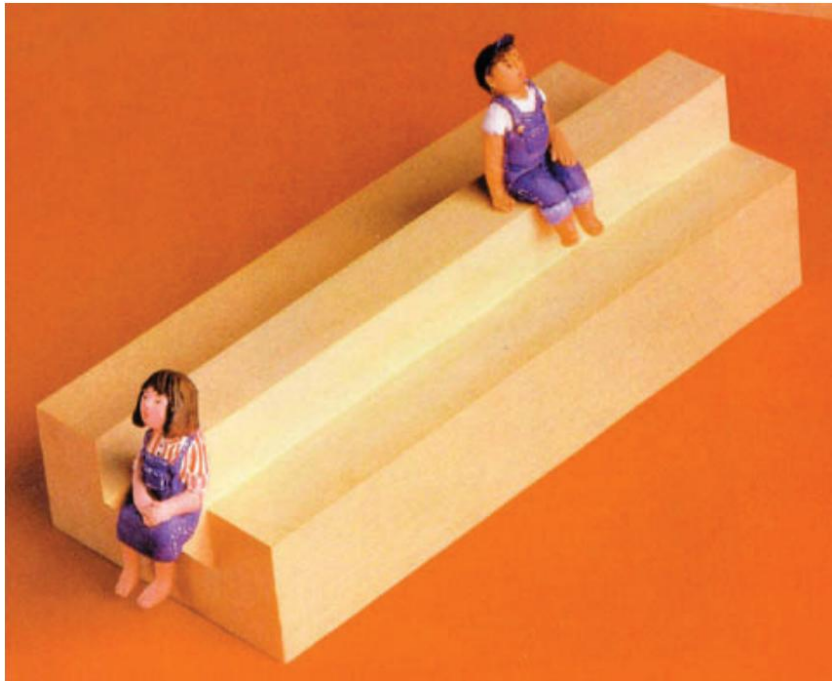
- An example of visual perception in action can be seen when **we look at a simple object, such as a ball**.
- When we see a ball, our eyes detect the light that is reflected off its surface and send this information to the brain.
- The brain then processes this information to create a visual **representation of the ball, including its size, shape, color, and texture.**

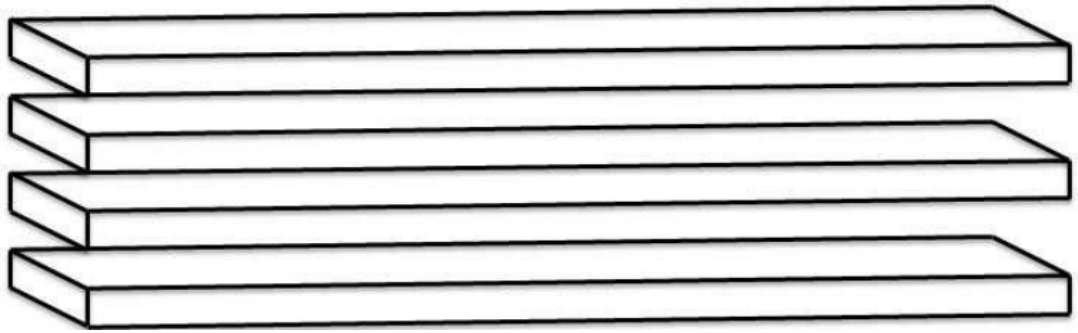
INTRODUCTION TO VISUAL PERCEPTION

- Perception is **studied to better control the presentations of data** and eventually to utilize or exploit human perception.
- Not paying attention to perception will lead to problems in visualization.
- How do we know that our visual representations are not interpreted differently by different viewers?
- *How can we be sure that the data we present is understood?*

INTRODUCTION TO VISUAL PERCEPTION

How can we be sure that the data we present is understood?

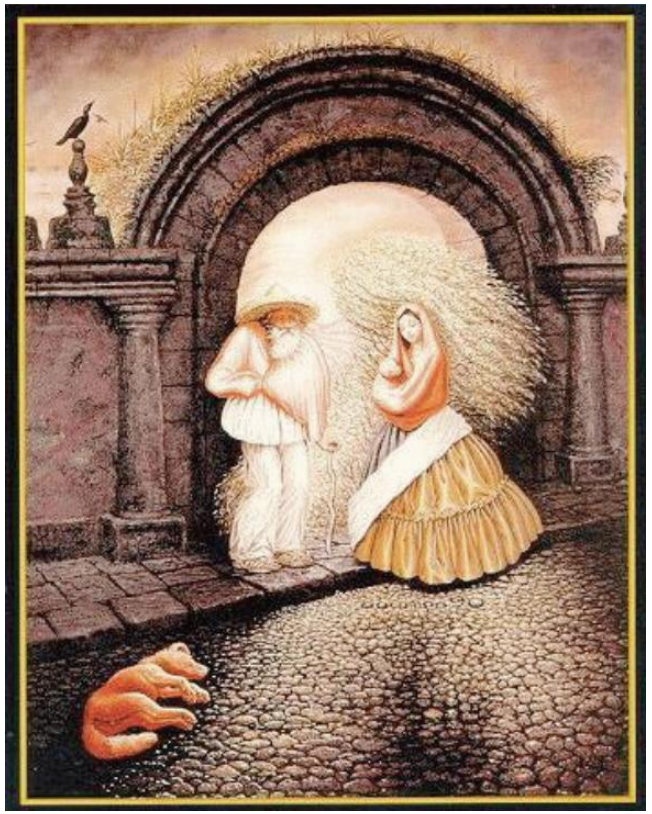




Figures highlight our inability to notice visual problems except on more detailed perusal.

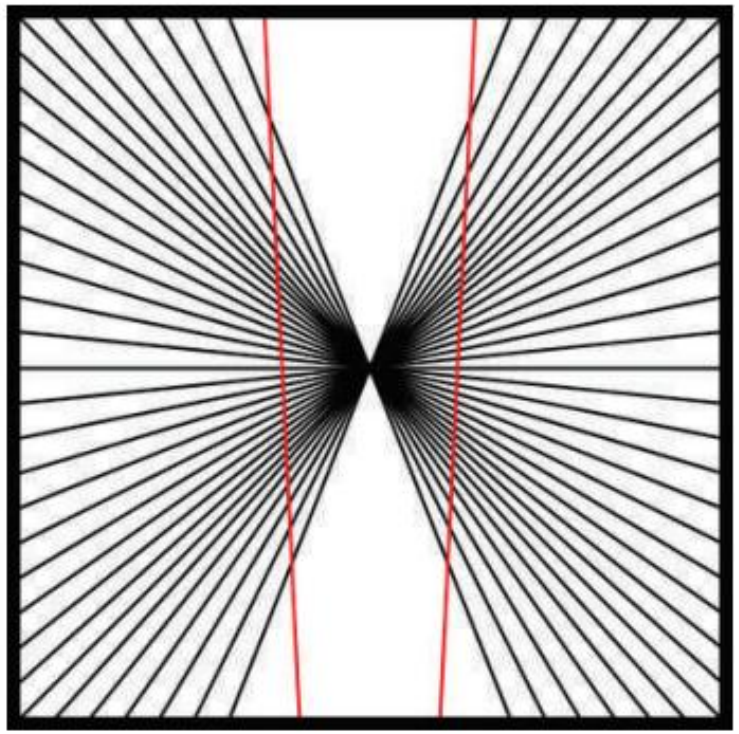
INTRODUCTION TO VISUAL PERCEPTION

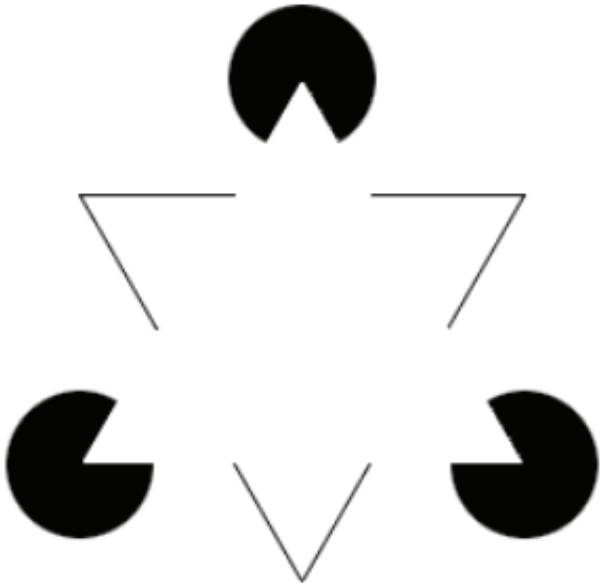
- *Visual representations of object are often misinterpreted* either because they do not match our perceptual system or they are intended to be misinterpreted.



INTRODUCTION TO VISUAL PERCEPTION

Some illusions:





INTRODUCTION TO VISUAL PERCEPTION

Key Principles of Visual Perception Applied to Data Visualization

The field of cognitive psychology provides a foundational understanding of how humans organize and interpret visual information.

Applying these principles is critical for effective data visualization

1. Gestalt Principles
2. Pre-attentive Attributes

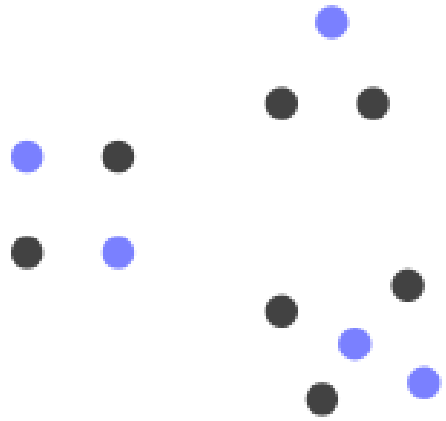
GESTALT PRINCIPLES

- Principles or laws of human perception that describe how humans group similar elements, recognize patterns and simplify complex images when we perceive objects

1. Similarity
2. Proximity
3. Enclosure
4. Connection
5. Continuity
6. Symmetry
7. Closure

GESTALT PRINCIPLES

SIMILARITY

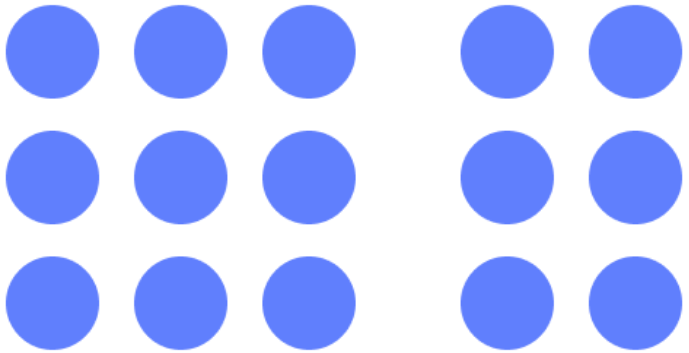


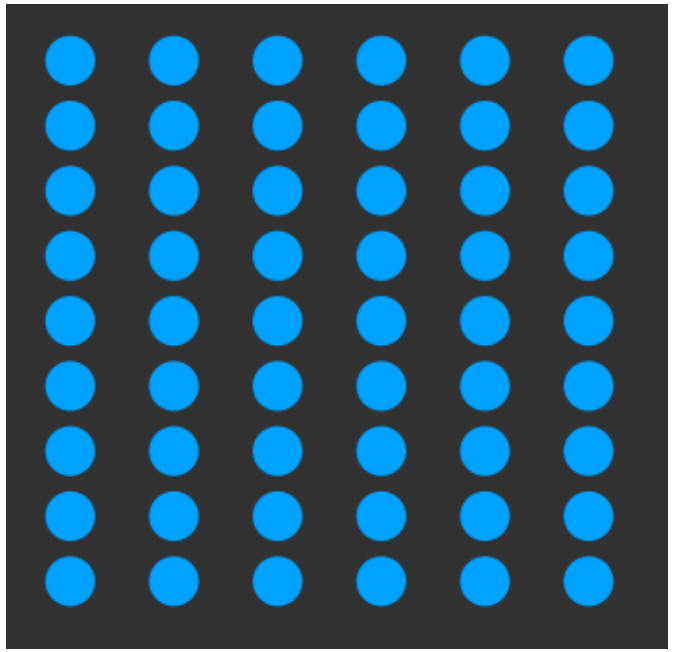
- Elements that share similar visual characteristics (e.g., color , shape, size) are perceived as related or part of the same group.

GESTALT PRINCIPLES

Proximity

- Objects placed close together are perceived as belonging to a group.

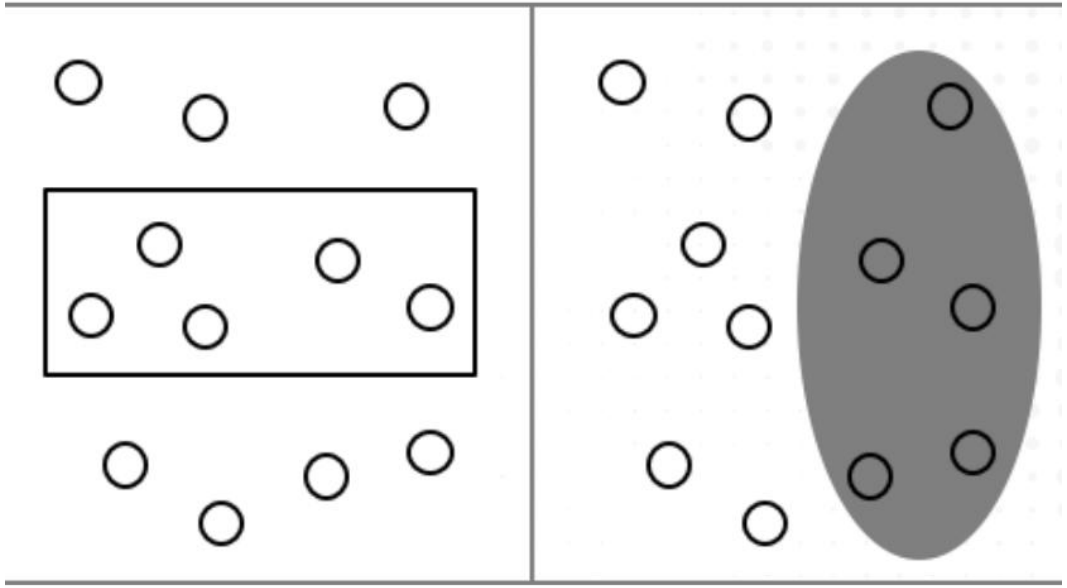




GESTALT PRINCIPLES

Enclosure

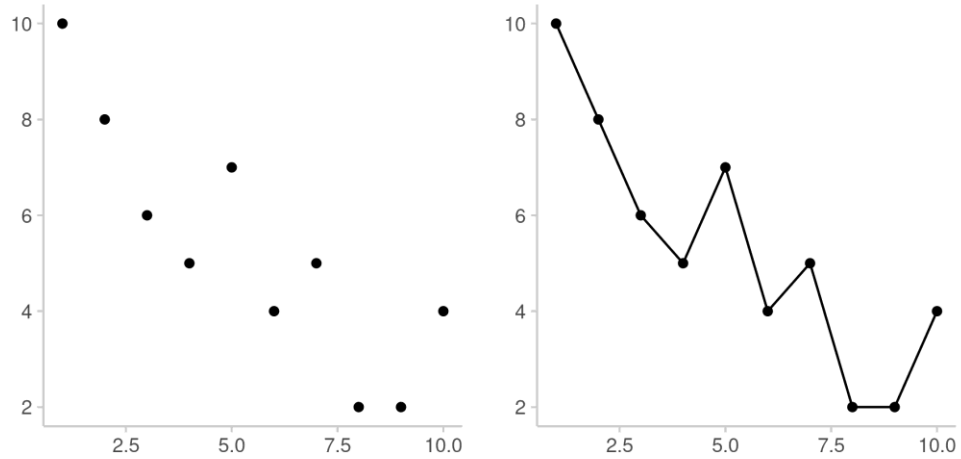
- Objects that are physically enclosed together are thought as belonging to part of a group.
- It doesn't take a very strong enclosure to do this: light background shading is often enough

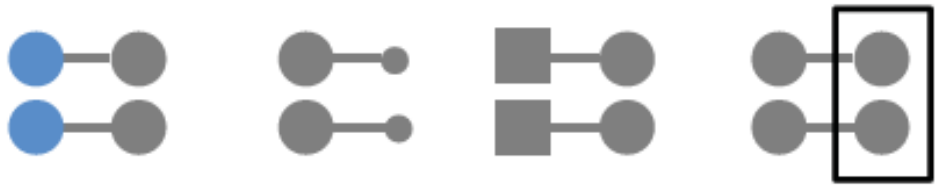


GESTALT PRINCIPLES

Connection

- Objects that are physically connected are perceived as a part of a group
- Connectedness dominates proximity and similarity
- The connective property isn't typically stronger than enclosure

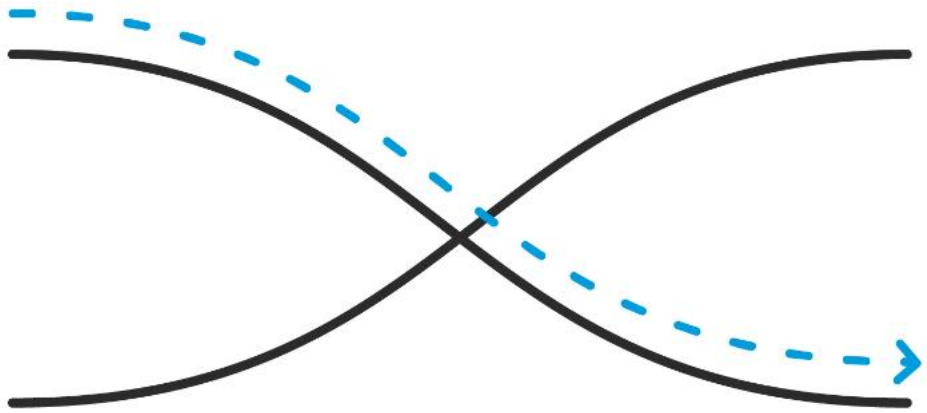




GESTALT PRINCIPLES

Continuity

- Human eye will follow smoothest path and perceive elements aligned in a way that suggests a continuous line or curve as being more related.



Symmetry

- Humans prefer balanced, harmonious, and simple compositions.
- Designs that incorporate symmetry and order are perceived as stable and aesthetically pleasing, contributing to visual comfort.

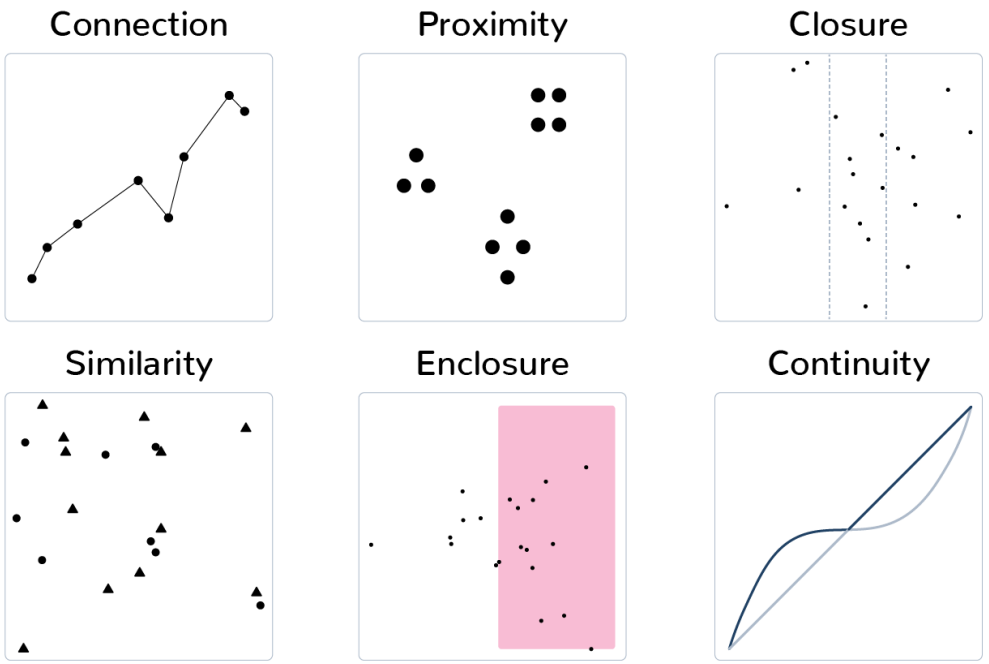
GESTALT PRINCIPLES

Closure:

- The closure concept says that people like things to be simple and to fit in the constructs that are already in our heads.
- The brain tends to perceive incomplete shapes or figures as complete, filling in the missing gaps to create a whole. This can be used to simplify designs by implying boundaries rather than explicitly drawing them.

GESTALT PRINCIPLES

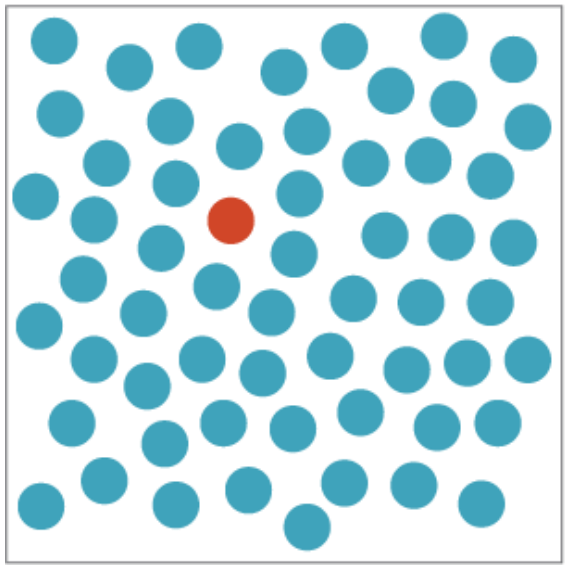
Study Material: Storytelling with Data by Cole Nussbaumer Knaflic (Chapter 3)

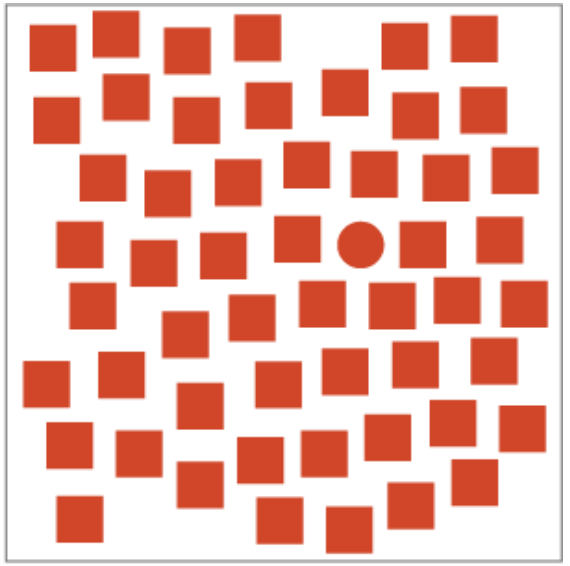


KNOWING OF PERCEPTUAL SYSTEM

Pre-Attentive Attributes:

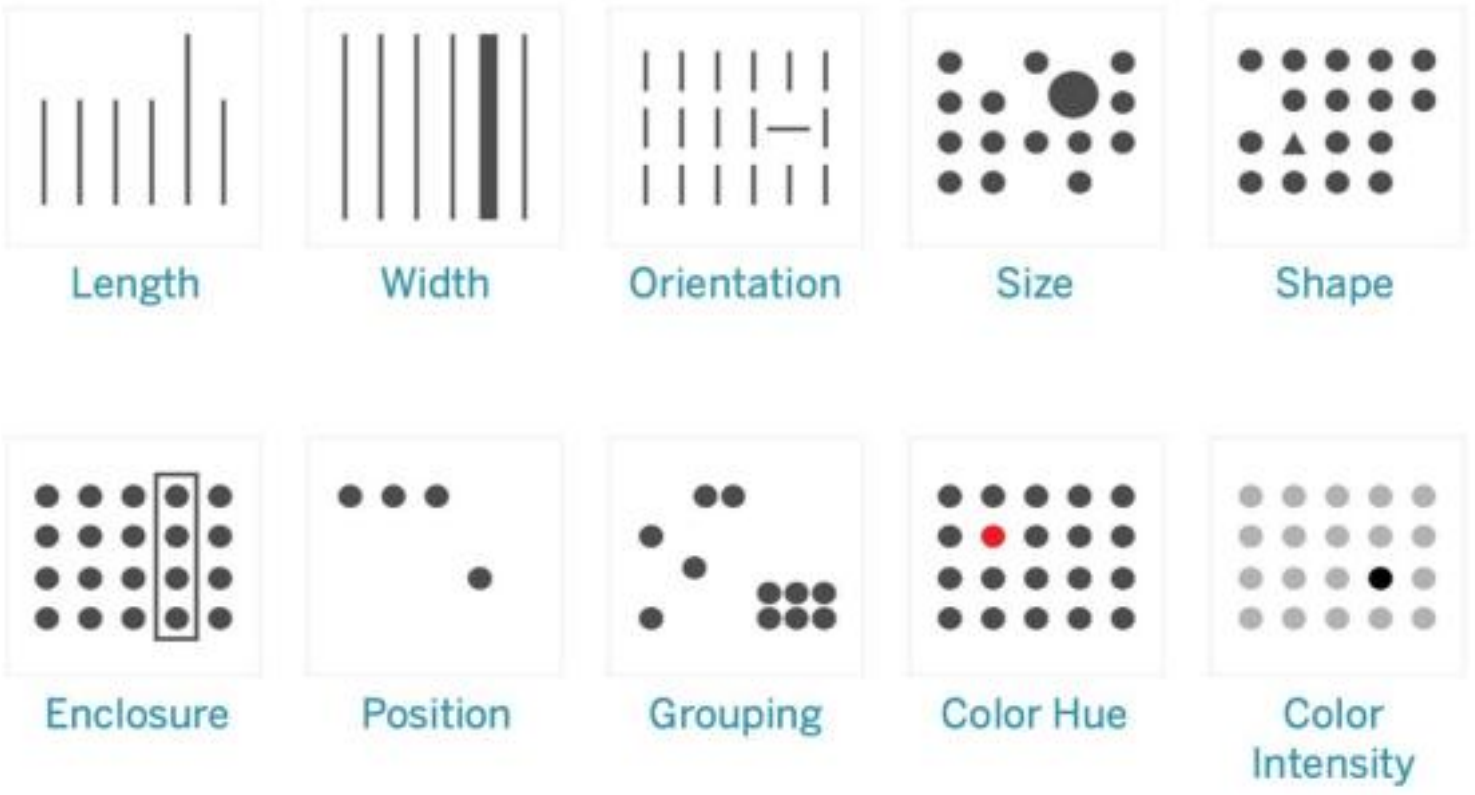
- These are visual properties that are processed by our visual system automatically and unconsciously before we even consciously focus on the image.
- Leveraging these attributes helps immediately draw attention to important data points.





KNOWING OF PERCEPTUAL SYSTEM

Pre-Attentive Attributes



VISUAL REPRESENTATION OF DATA

- Visual representation of data involves **the use of graphical elements to present complex data sets** in a way that is easy to understand and interpret.
- Use of **graphs, shapes, color** that allow users to quickly grasp key insights from large amounts of data.

1. Simple Text

- When there is just a number or two to share,

  simple text can be a great way to communicate

VISUAL REPRESENTATION OF DATA

2. Tables

- Tables are great for just that-communicating to a mixed audience whose members will each look for **their particular row of interest.**
- If there is need to communicate multiple different units of measure, this is also typically easier with a table than a graph.

Variation: Heatmap

Student	Physics	Chemistry	Math	English
Peter	80	65	80	74
Samuel	90	85	72	65
Ruth	78	75	60	82
John	82	72	85	92
Mark	70	60	65	60
Andre	75	80	70	82

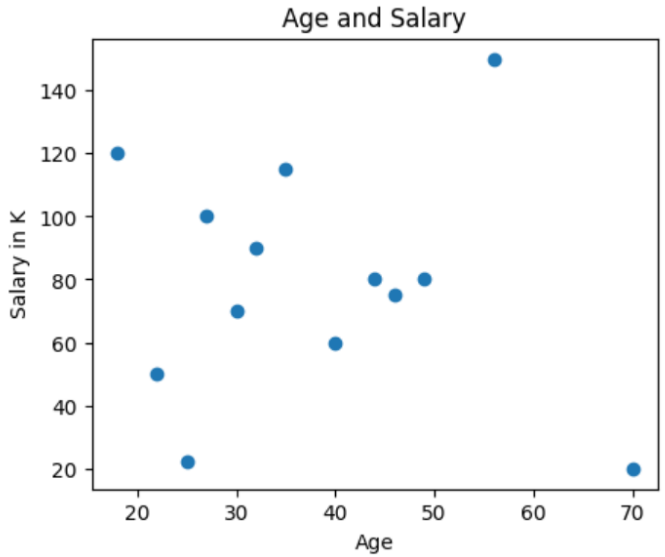
VISUAL REPRESENTATION OF DATA

3. Graphs

- Graphs *interact with our visual system*, which is faster at processing information.
- Four categories: Points, lines, bars and area.

Points : Scatterplot

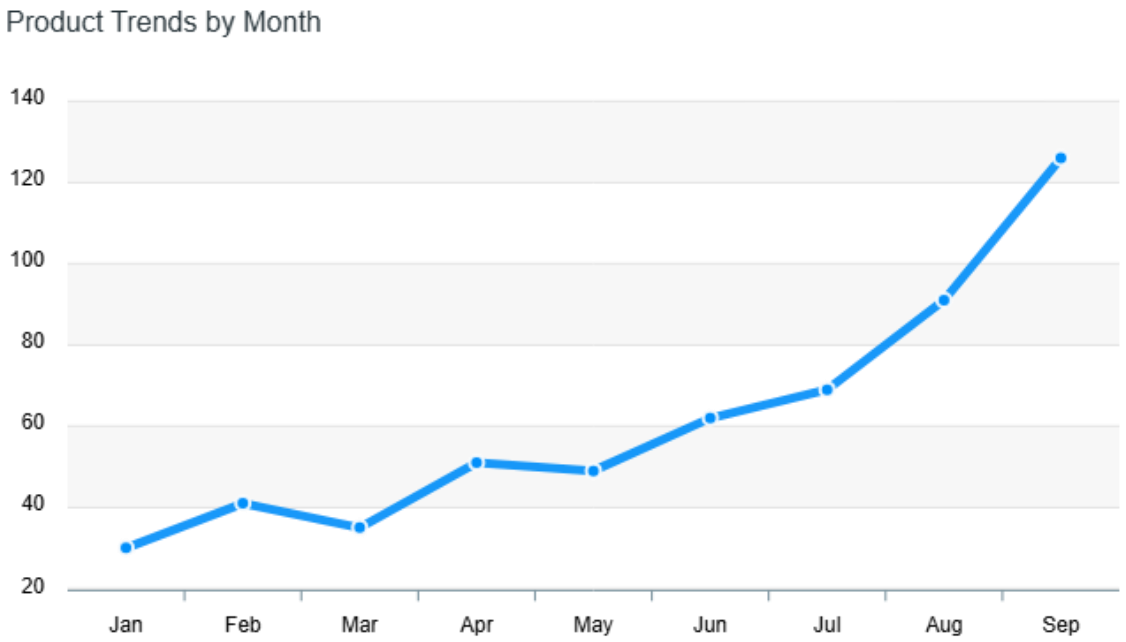
- Useful for showing the *relationship between two things*, because it allow to encode data simultaneously on horizontal x-axis and vertical y-axis.
- It allows seeing whether and what relationship exists.



VISUAL REPRESENTATION OF DATA

Lines: Line graph

- Line graphs are most commonly used to plot continuous data. The *continuous data is in some unit of time: days, months, quarters or years.*



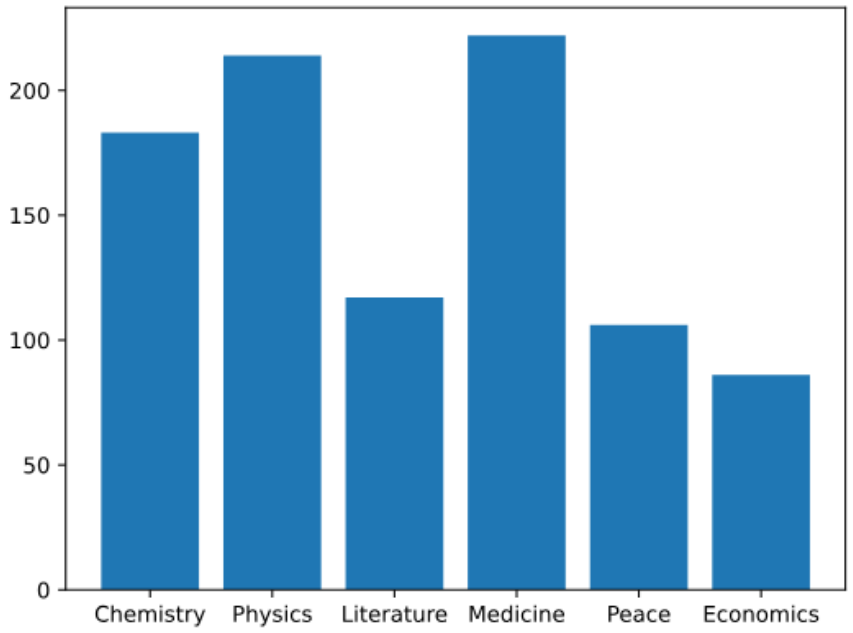
VISUAL REPRESENTATION OF DATA

Bars: Vertical bar chart, stacked vertical bar chart, horizontal

- A bar chart is used when we have *numerical data that splits nicely into different categories.*
- Able to quickly see trends within your data.

Variations: stacked bar chart,

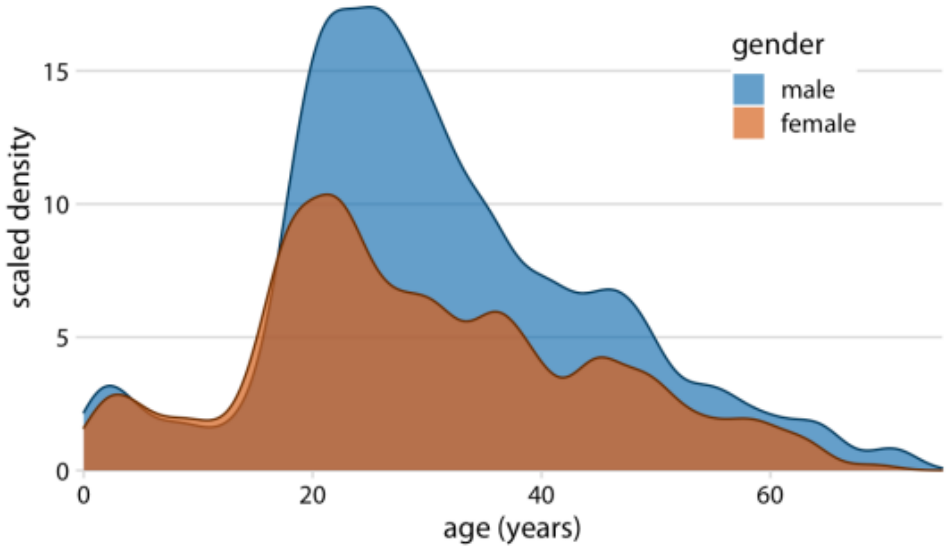
grouped bar chart,



VISUAL REPRESENTATION OF DATA

4. Areas

- To show **proportion or distribution** of certain categorical group.
- Used less compared to point line and bars.



DATA ABSTRACTION

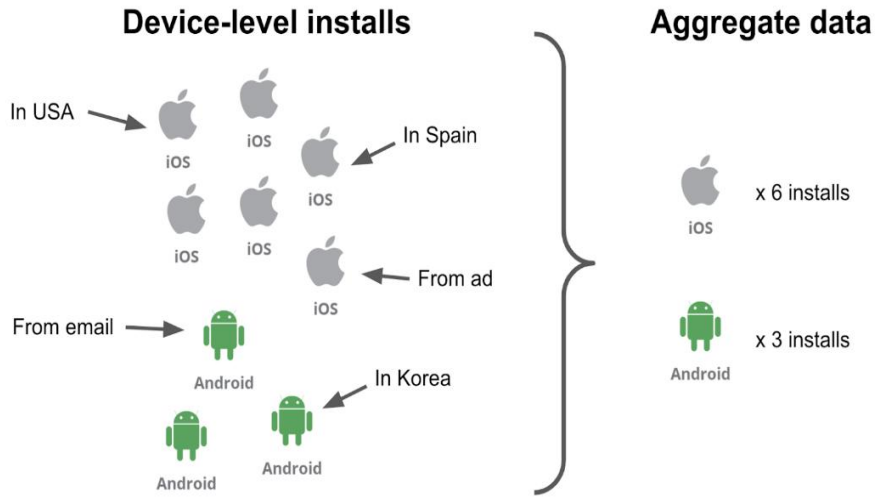
- Data abstraction is the process of simplifying complex data by *focusing on the most important features or characteristics*, while ignoring or hiding irrelevant details.
- *Involves reducing the amount of data* presented to the user to provide a clearer, more concise view of the underlying patterns or trends.

i. Aggregation
ii. Sampling
iii. Filtering
iv. Clustering
v. Dimensionality Reduction etc.

DATA ABSTRACTION

1. Aggregation

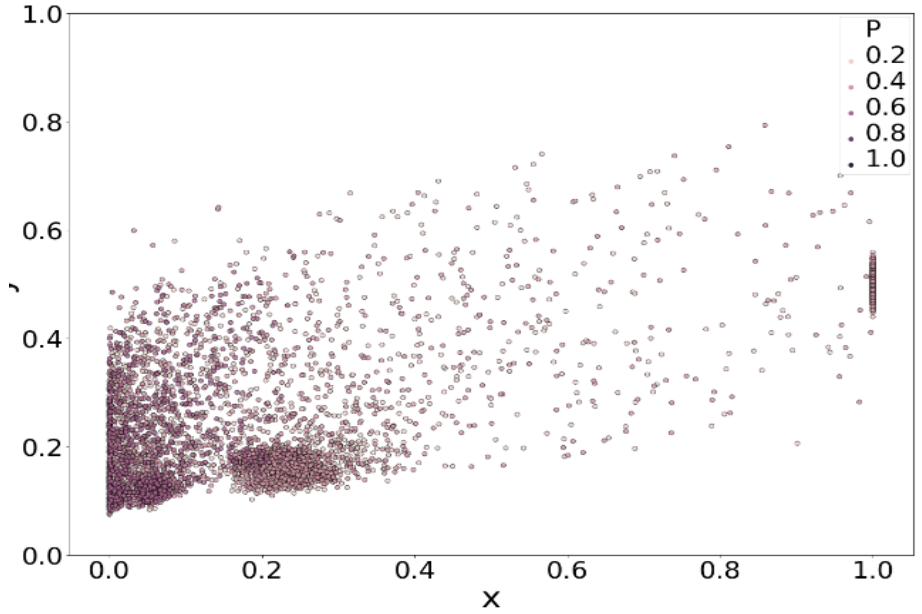
- Aggregation involves *combining multiple data points into a single summary value*. This is often done to provide a higher-level view of the data, or to make it easier to compare values across different groups.
- **E.g.:** A bar chart that shows the sales figures for different products can be aggregated by product category to provide a summary of the total sales for each category.



CONTINUE

2. Sampling

- Sampling *involves selecting a subset of the data for visualization*. This is often done to provide a representative view of the data, or to reduce the amount of data being presented.
- **E.g.:** A scatter plot that shows the relationship between a person's age and their income can be sampled to include only a subset of the population, such as individuals within a certain age range.



CONTINUE

3. Filtering

- Filtering involves selecting a *subset of the data based on certain criteria.*
- This is often done to focus on a specific aspect of the data, or to remove outliers or irrelevant data points.

- **E.g.:** A heat map that shows the temperature distribution of a region can be filtered to show only temperatures above a certain threshold, or to exclude data points from areas with inconsistent or unreliable temperature readings.

CONTINUE

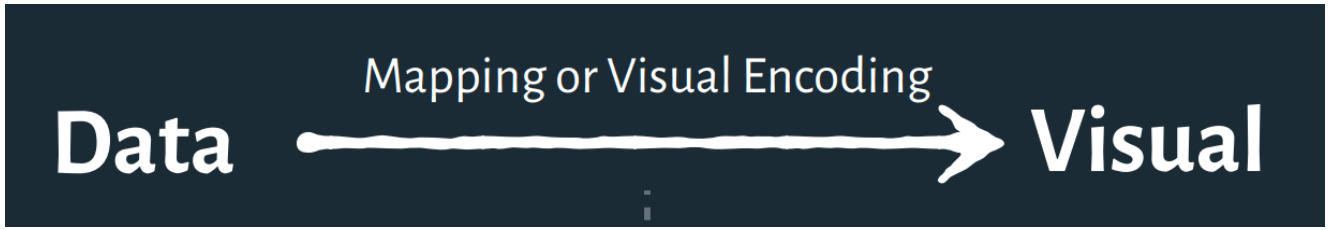
4. Dimensionality Reduction

- Dimensionality reduction *involves reducing the number of variables* used to represent the data.
- This is often done to simplify the data and improve visual clarity.

- **E.g.:** A line graph that shows the trend of stock prices over time can be simplified by only showing the closing price of the stock at the end of each day, rather than including all of the intermediate price values throughout the day.

VISUAL ENCODINGS

- is the process of translating data attributes into visual elements and properties of a graphic.
- When a chart is created, decisions are made about how the data's characteristics will be represented visually.

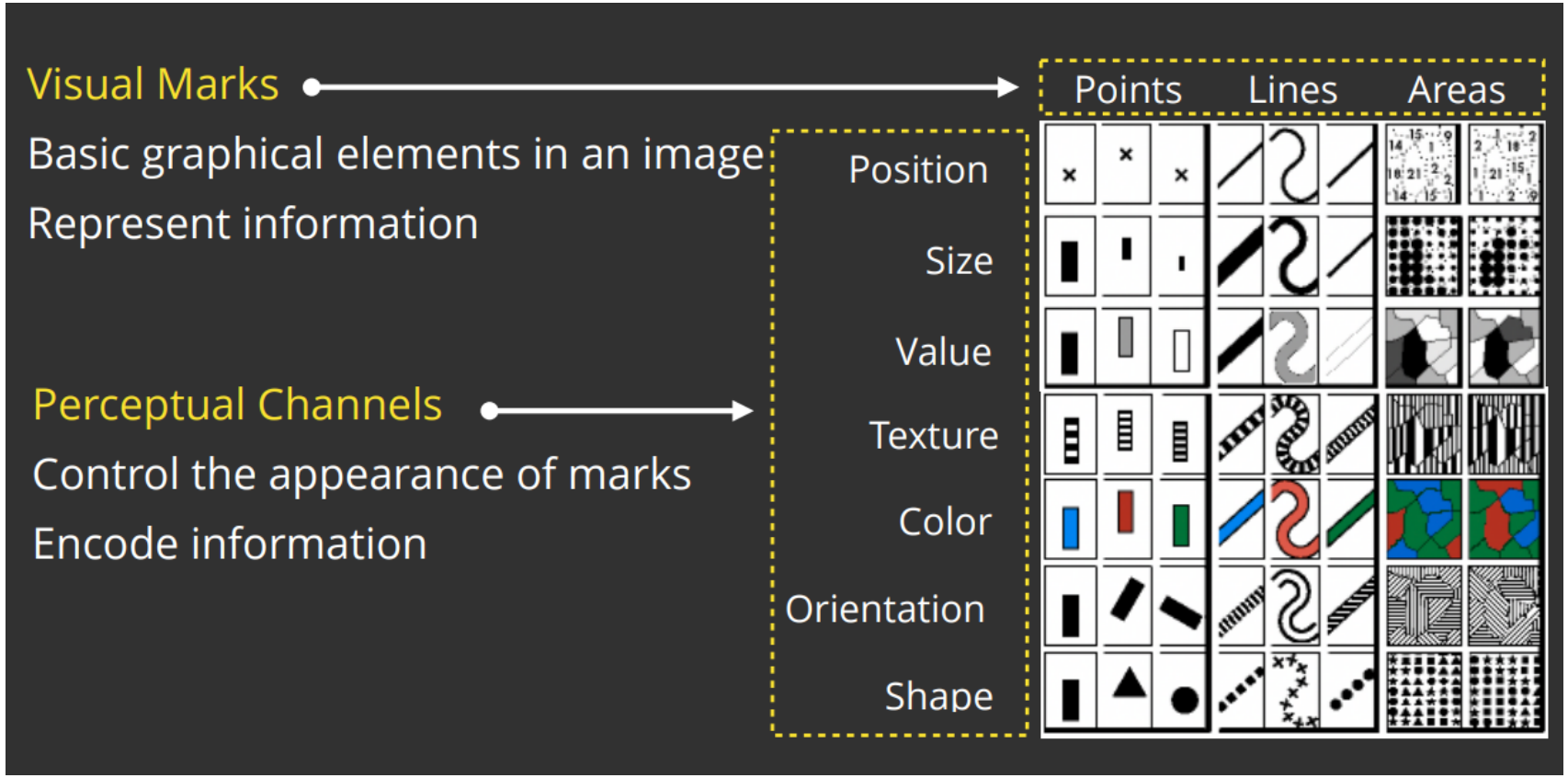


- In a **bar chart:** The *height* of the bar encodes a numerical value. The *position* along the x-axis encodes a category.
- In a **scatter plot:** The *x-position* encodes one numerical variable, and the *y-position* encodes another numerical variable.

VISUAL ENCODINGS

Visual encodings

Visual encodings can be described as combination of two aspects: graphical elements called marks and visual channels to control their appearance.



VISUAL ENCODINGS

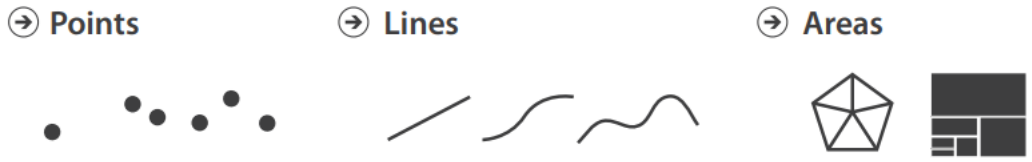
Visual Variables or Encoding Channels

- Position
- Color
- Shape
- Size
- Orientation
- Texture

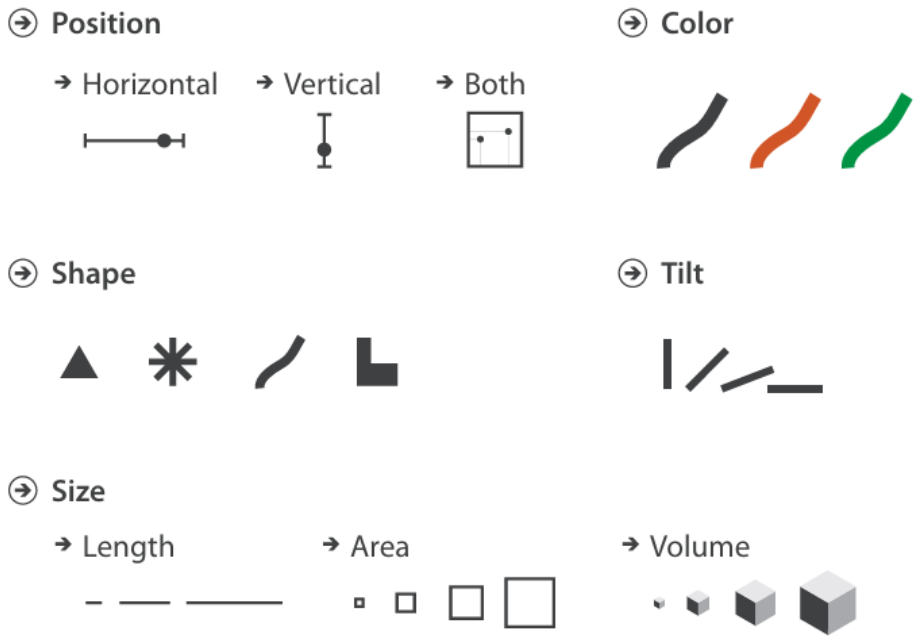
- It is technique within Data Visualization. It is like choosing and applying the visualization materials and techniques
- Taking data attributes and assigning it to visual variables.
- Process of choosing different channels to encode the data attributes

VISUAL ENCODINGS

- A **mark** is a basic graphical element in an image.



- A **visual channel** is a way to control the appearance of marks. These are the ways to change how a visual element looks.



PRINCIPLES OF VISUAL ENCODINGS

Expressiveness Principle

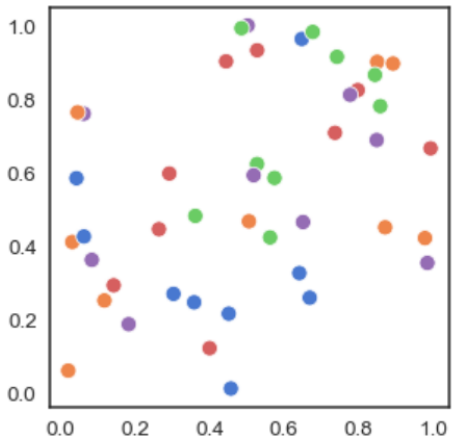
- A visual encoding is expressive if it accurately represents all, and only, the information in the dataset attributes.

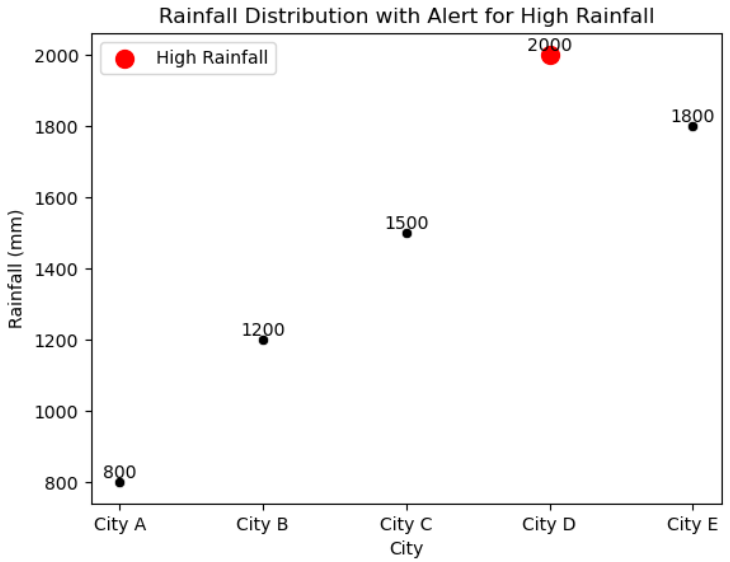
Effectiveness Principle

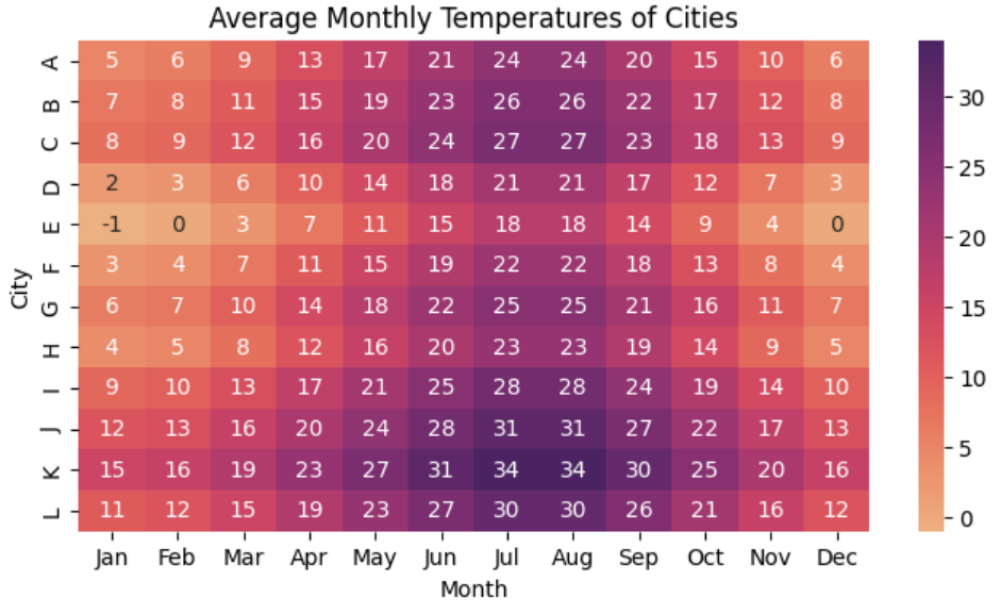
- An encoding is effective if the information it conveys can be readily and accurately perceived by the human eye.
- Some visual channels are more effective than others for certain types of data.
- For instance, humans are very good at discerning differences in position and length, making them highly effective for quantitative comparisons. Area and volume are generally less effective for precise quantitative judgments.

USE OF COLORS

- Color is one of the most powerful and intuitive visual variables in data visualization.
- When applied thoughtfully, color can significantly enhance comprehension, highlight insights, and make a visualization more engaging.







USE OF COLORS

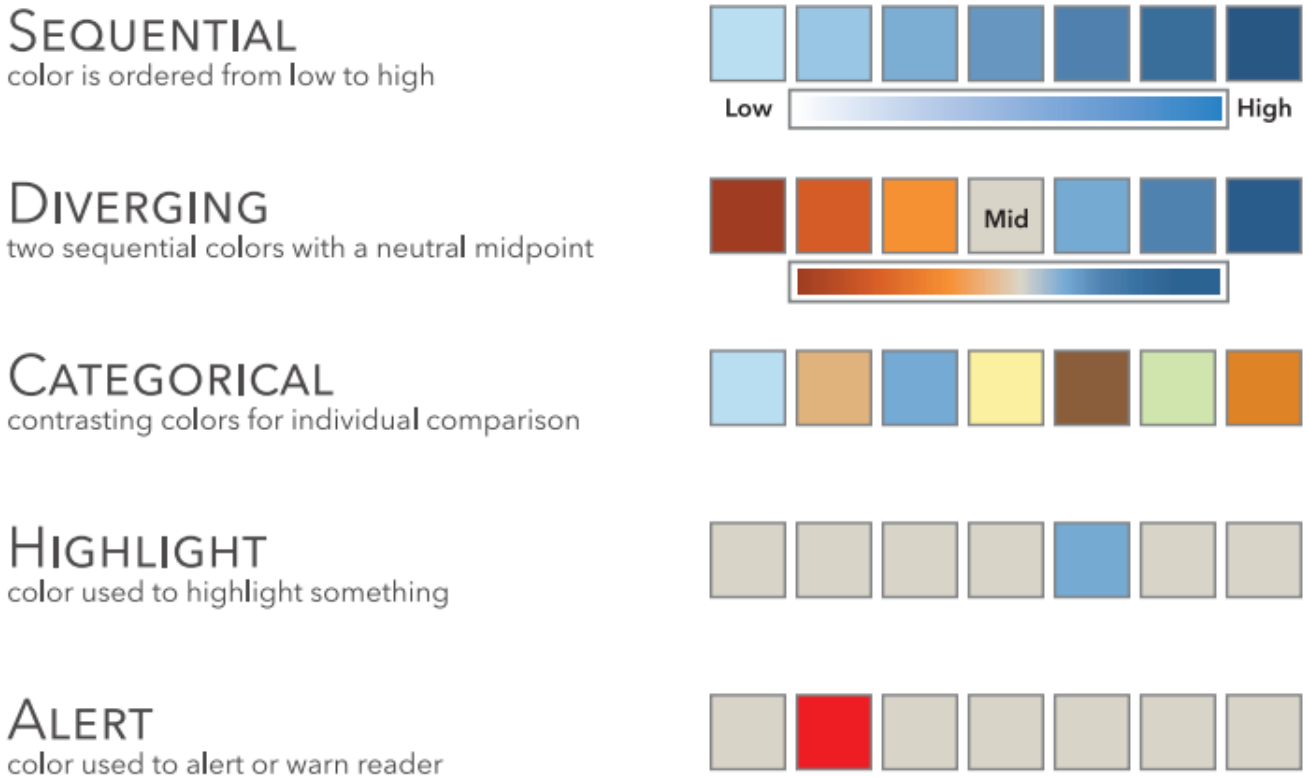
Used to :

i. draw attention of the reader
ii. highlight portion of data
iii. distinguish between different categories

- Color should be used in data visualization in three primary ways: *sequential, diverging, and categorical.*
- In addition, there is often the need to highlight data or alert the reader of something important.

USE OF COLORS

The big book of dashboards

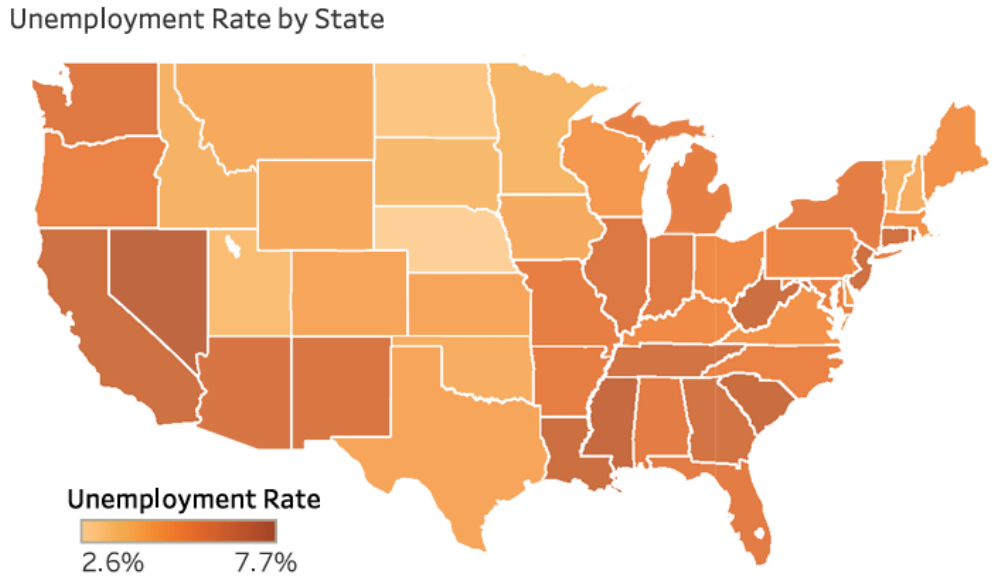


USE OF COLORS

Sequential color (Representing Order) : use of single color from light to dark

- Variations in saturation of a single hue can indicate increasing or decreasing values.
- E.g., A heatmap where darker shades of hue represent higher temperatures.

- Figure shows the unemployment rate by state using
- A sequential color scheme.

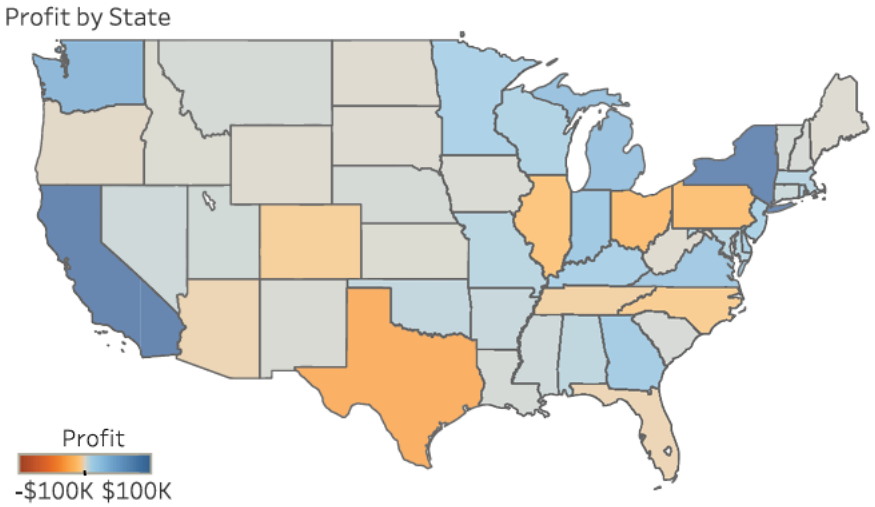


USE OF COLORS

Diverging color:

- used to show a range diverging from a midpoint.
- Two different hues anchored by a neutral middle color are used for data that has a meaningful midpoint, often showing deviation from a norm (e.g., above/below average, positive/negative).

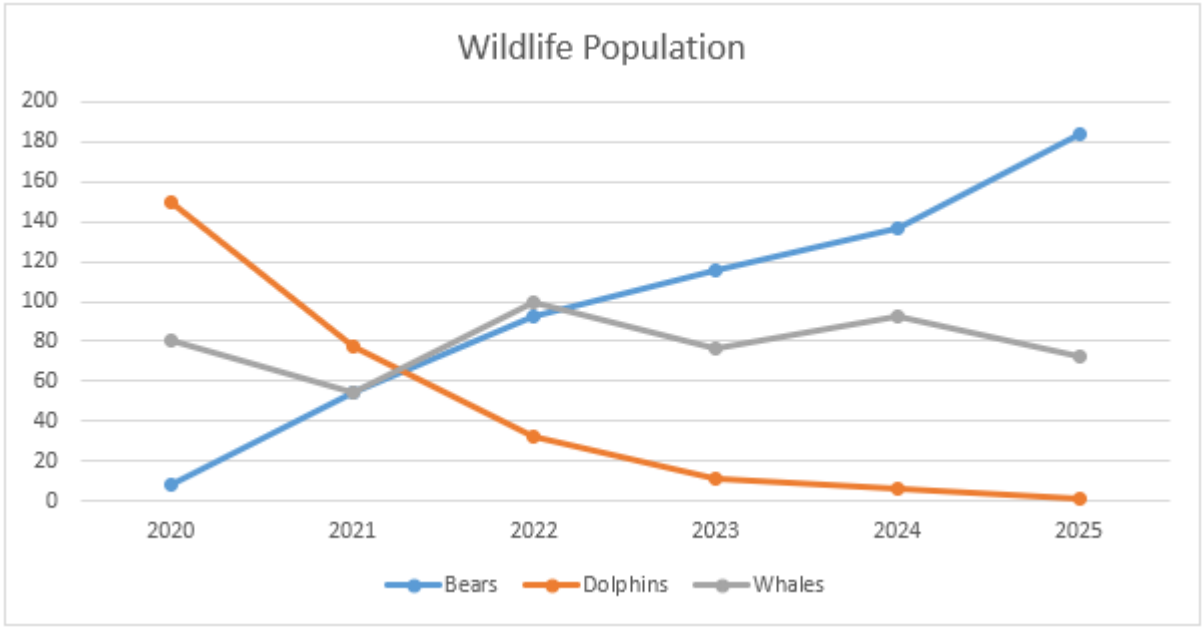
- E.g., Red for negative values, blue for positive values, with white or light gray in the middle for zero.



USE OF COLORS

Categorical Color:

- Different hues (e.g., red, blue, green) can be for separating distinct, groups or categories.
- E.g., Different lines in line chart.

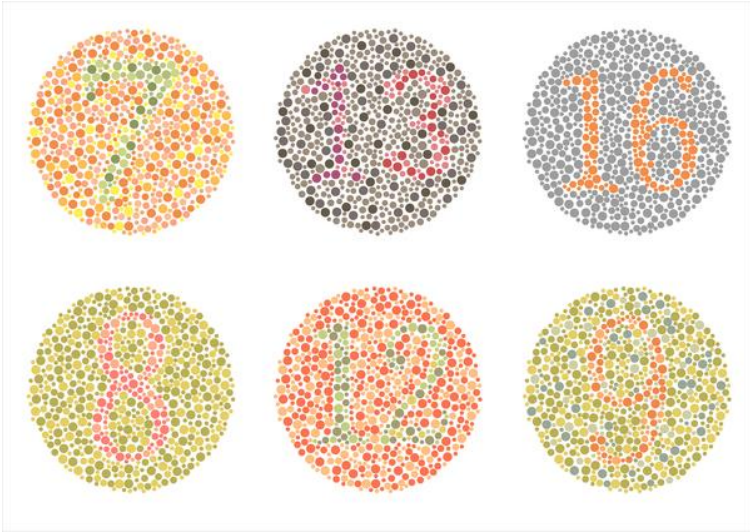


PERCEPTUAL ISSUES

When using color in data visualization, there are some important considerations to keep in mind:

Color Vision Deficiency

- Approximately 8% of men and 0.5% of women have some form of color vision deficiency, which can affect their ability to distinguish between certain colors.
- This deficiency is caused by a lack of one of three types of cones within the eye needed to see all color.



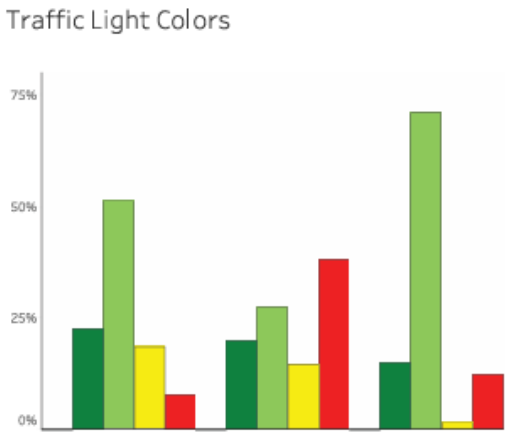
PERCEPTUAL ISSUES

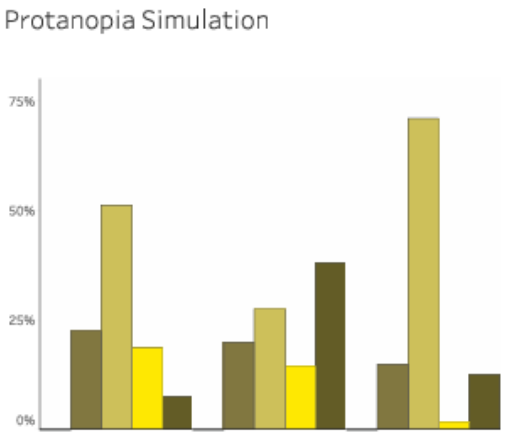
Color Vision Deficiency

Three types of CVD:

- Protanopia is the lack of long-wave cones (red weak).
- Deuteranopia is the lack of medium-wave cones (green weak).
- Tritanopia is the lack of short-wave cones (blue).

- The primary problem among people with CVD is with the colors red and green.
- This is why it is best to avoid using red and green together





PERCEPTUAL ISSUES

Consistency

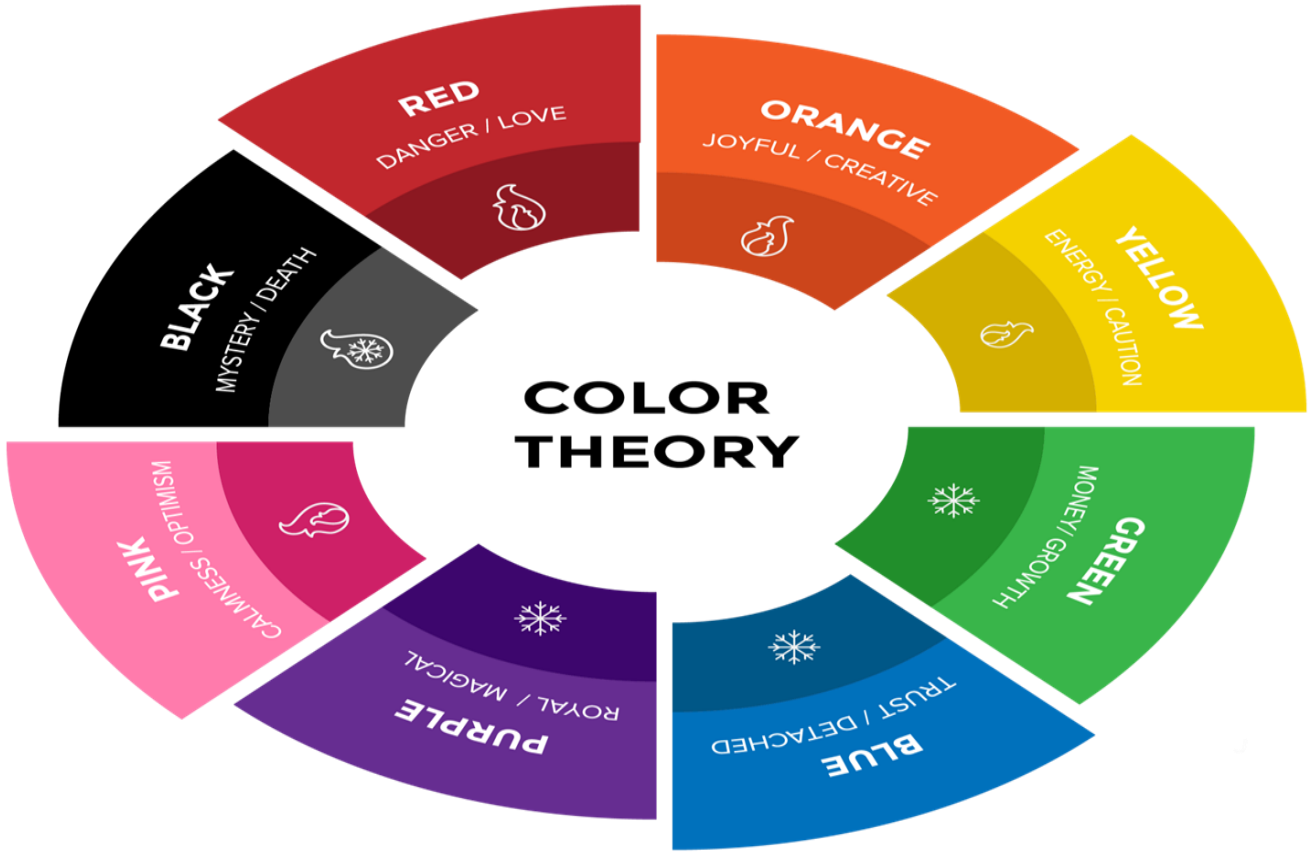
- Using consistent color schemes throughout a data visualization can make it easier for the viewer to understand the data and identify patterns or relationships.
- Using too many colors or changing color schemes can create distraction.

Context

- The use of color should always be considered in the context of the data being presented and the goals of the visualization.

USE OF COLORS

Context

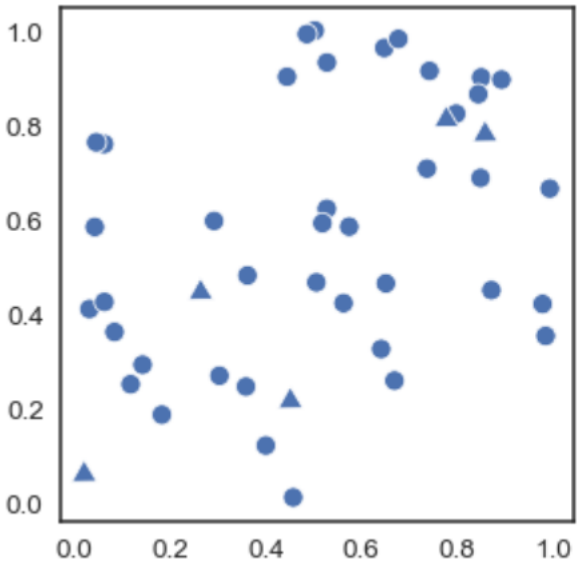


PERCEPTUAL ISSUES

- Perceptual issues can arise in visual representation when the visual cues used to represent data values are not aligned with the way the human brain processes visual information.

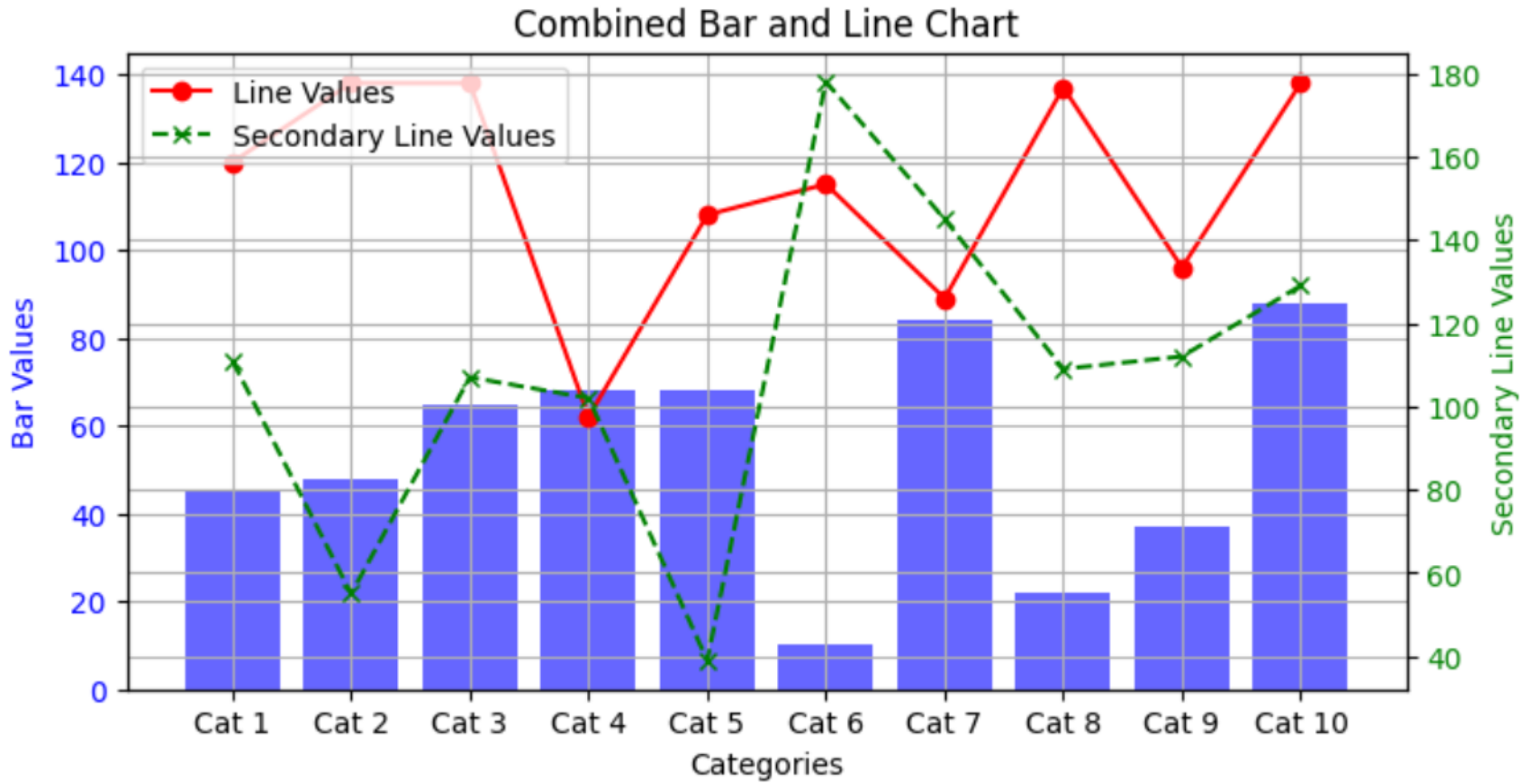
- To address perceptual issues, designers can use techniques such as:

  i. Gestalt Principles
  ii. Data scaling
  iii. Labeling



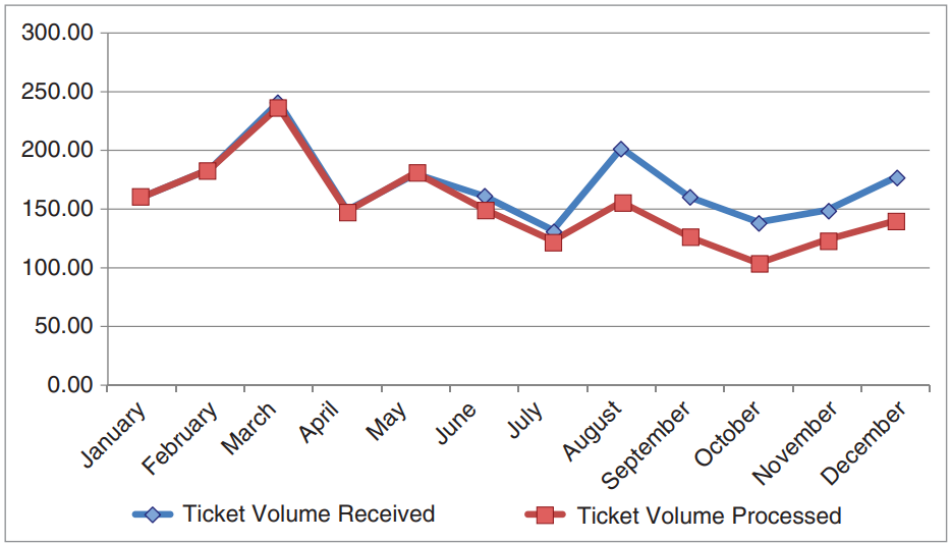
INFORMATION OVERLOADS

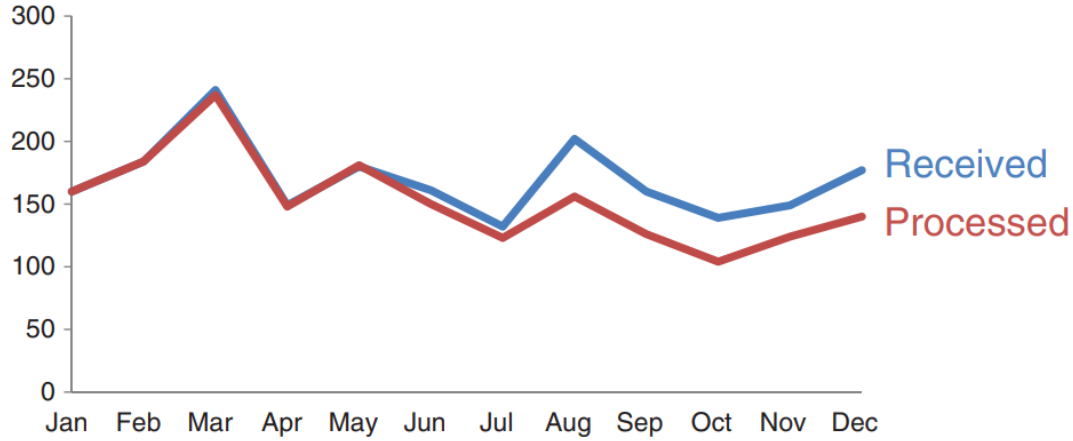
- Information overload occurs when a visual display presents *too much information* at once.



INFORMATION OVERLOAD

- Information overload occurs when a visual display presents *too much information at once*, making it difficult for users to effectively process and interpret the data.
- This can occur when the visual display *is too cluttered* or when too many variables are presented at once.





INFORMATION OVERLOAD

Data-ink Ratio

- Data-ink: This is the essential ink that directly represents the data. If it is removed, information about the data is lost.

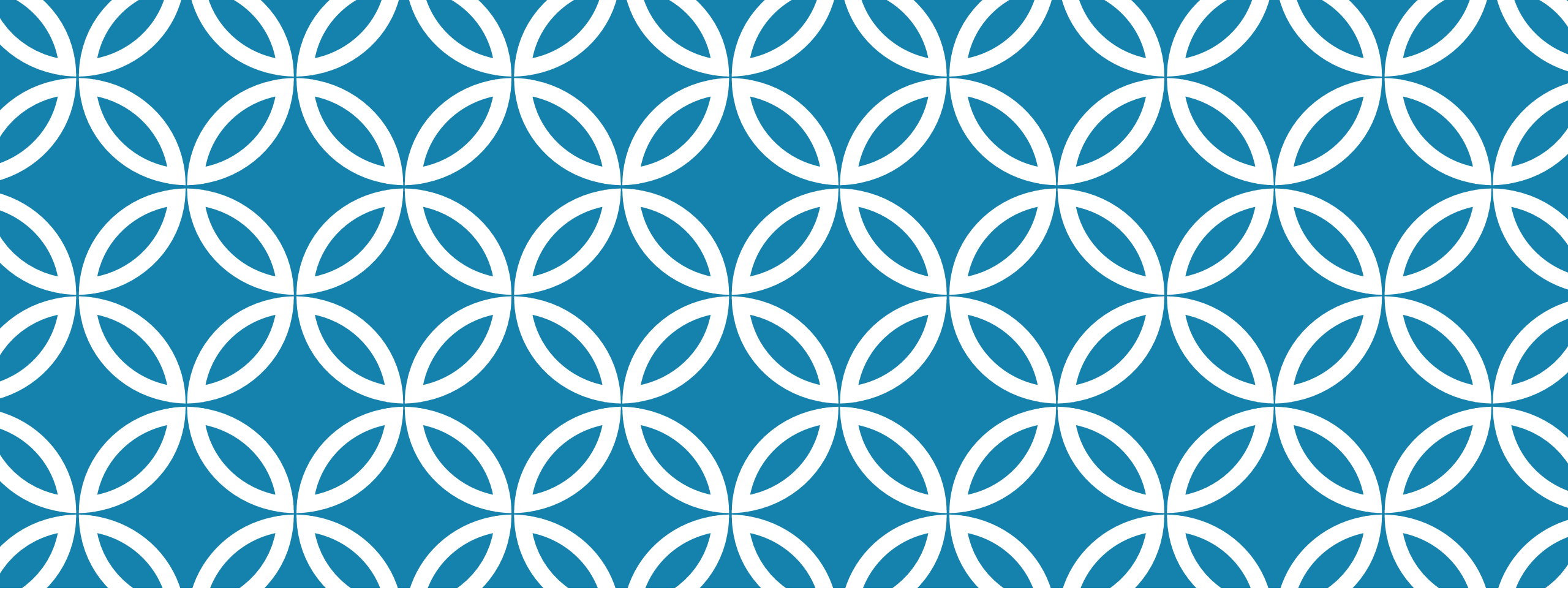
- $$\text{Data-ink Ratio} = \frac{\text{Data-ink}}{\text{Total ink used}}$$

- The goal is to **maximize the data-ink ratio**
- Eliminate unnecessary non-data-ink like heavy borders, redundant labels, or excessive grid lines

INFORMATION OVERLOAD

- When a visual display presents too much information at once, it can be difficult for users to identify patterns and relationships, make informed decisions, or draw meaningful conclusions.

- Techniques to avoid information overload
    i. Data abstraction
    ii. Hierarchical organization
    iii. Interactive visualizations



THANK YOU..