Principles of Data Visualization

Why visual rules matter & how design choices affect human understanding.
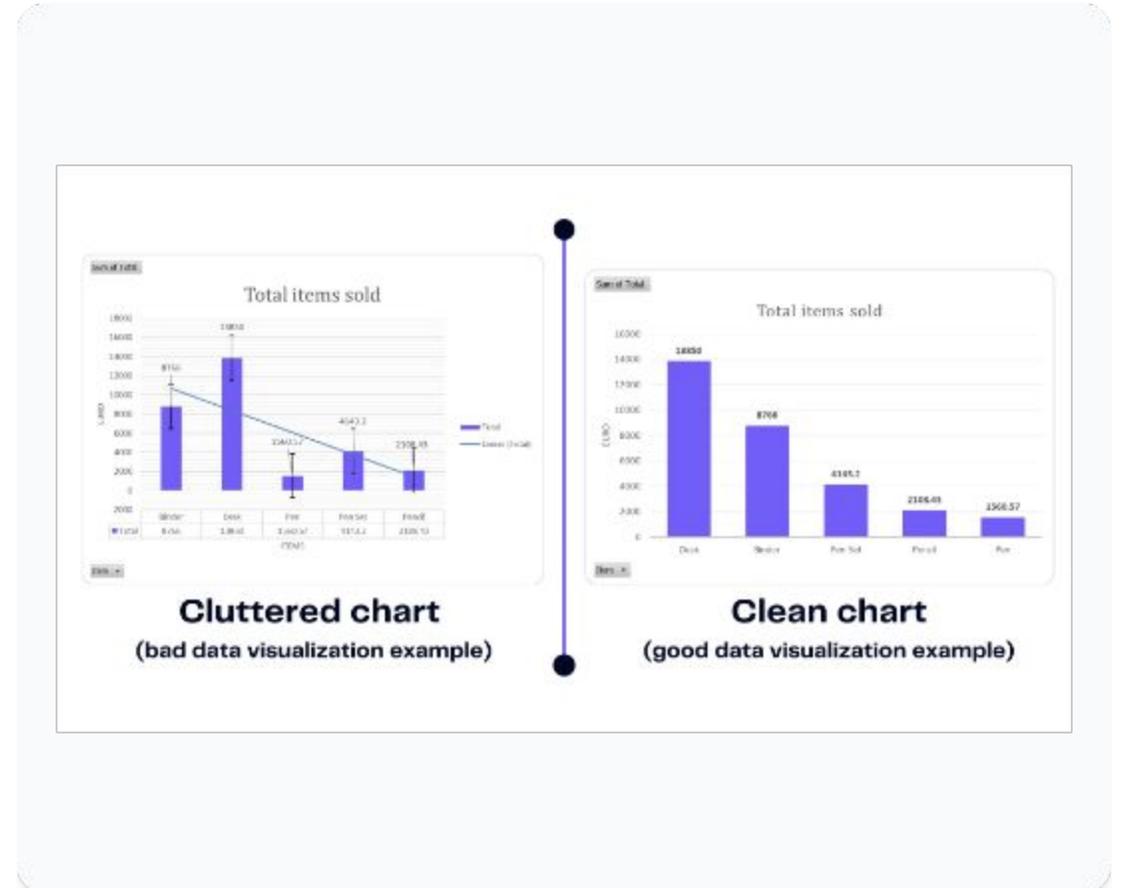
Learning Outcomes

By the end of this chapter, you will be able to:

- ✓ **Explain Core Principles:** Articulate the foundational theories behind effective visual communication.

- ✓ **Identify Design Failures:** Critically evaluate and pinpoint misleading or poor design choices in existing charts.

- ✓ **Apply Decision-Making:** Implement visualization principles strategically when creating new data representations.

- ✓ **Optimize Perception:** Design charts that align with human cognitive strengths rather than weaknesses.

Why Principles Matter

- ✓ **Not Just Decoration:** Visualization is a tool for thought, not an aesthetic ornament.

- ✓ **Communication First:** Its primary role is to transfer complex data into understandable insights.

- ✓ **High Stakes:** Poor visuals lead to flawed interpretations and detrimental business decisions.

Examples: Misleading social media infographics or deceptive political charts.

Total items sold

Cluttered chart
(bad data visualization example)

Total items sold

Clean chart
(good data visualization example)

Visualization as Communication

Data Encoding Process:

Data → Visual Encoding → Human Perception

✓ Humans interpret visuals much faster than raw text or tables.

✓ First impressions dictate the initial interpretation of data.

✓ Visuals bypass analytical thinking and move straight to perception.
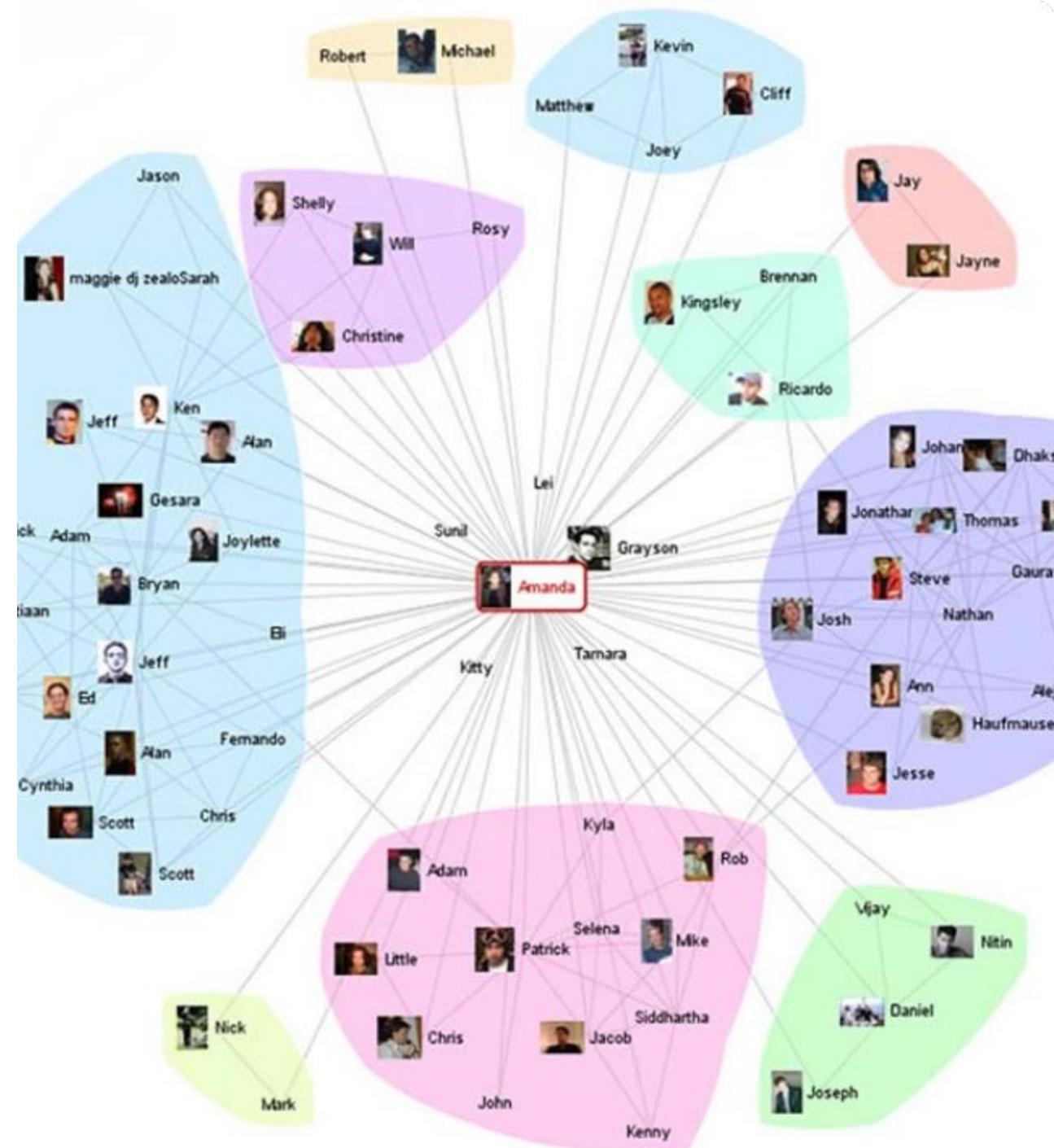
Human Visual Perception

Understanding what humans process best is key to choosing chart types.

Perceptual Task	Strength	Optimal Chart Type
Position & Length	✅ High Accuracy	Bar Charts, Scatter Plots
Direction & Angle	⚠️ Medium Accuracy	Line Charts, Pie Charts
Area & Volume	❌ Low Accuracy	Bubble Charts, 3D Charts
Color Intensity	❌ Low Accuracy	Heat Maps

Preattentive Attributes

Color

Differences in hue or intensity draw the eye instantly before conscious processing.

Size

Variations in width or length highlight relative importance or magnitude.

Position

The placement of an element in 2D space is the most accurate visual cue.

These features are detected in less than 250 milliseconds.

Visual Hierarchy

#1

Priority Messaging

Guiding the Viewer's Attention

Visual hierarchy ensures the most important information is consumed first.

- ✓ **Size:** Larger elements command more attention.

- ✓ **Contrast:** Darker or brighter colors stand out against neutral backgrounds.

- ✓ **Position:** The top-left corner is usually the first point of focus (F-pattern).
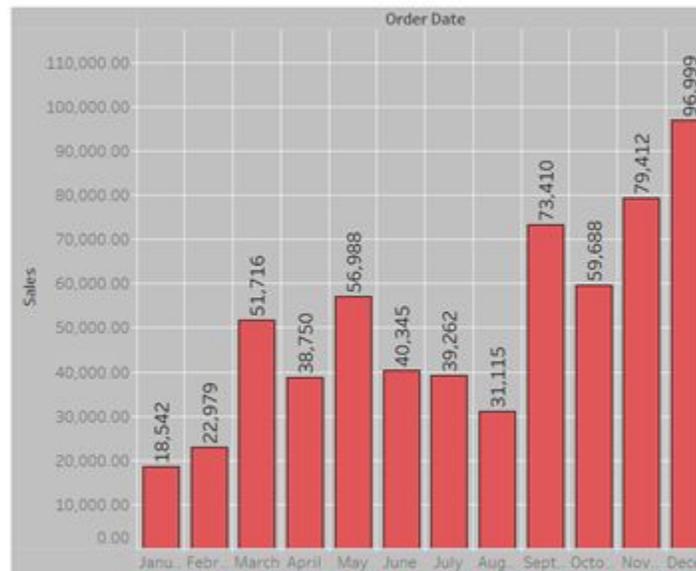
The Data-Ink Ratio

Edward Tufte's principle: Data-ink ratio = (ink used for data) / (total ink used).

Maximize Data-Ink │ Minimize Non-Data Ink
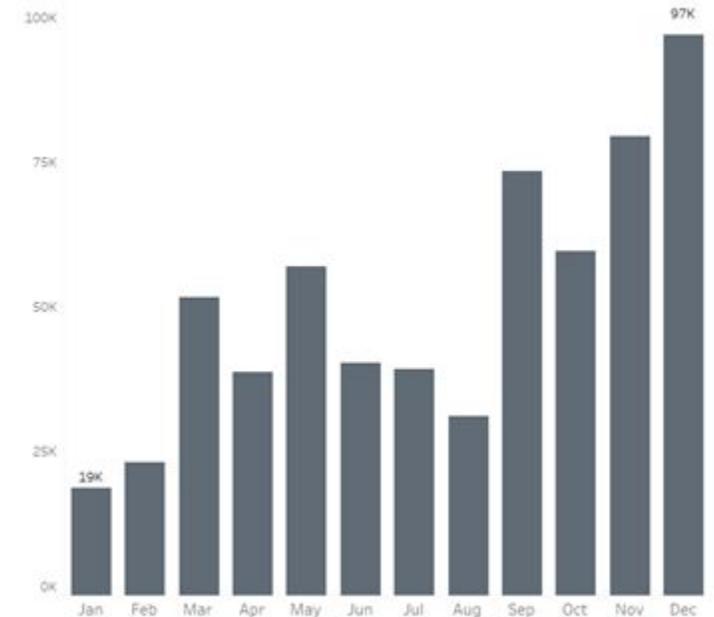
Non-Data Ink to Remove:

- Heavy gridlines
- Excessive borders
- Decorative backgrounds
- Redundant labels

Monthly Sales Analysis of a USA Superstore: Unveiling Revenue Trends and Seasonal Patterns for a Successful Business Year in 2020

Low Data Ink Ratio

USA Superstore Monthly Sales by Months, 2020
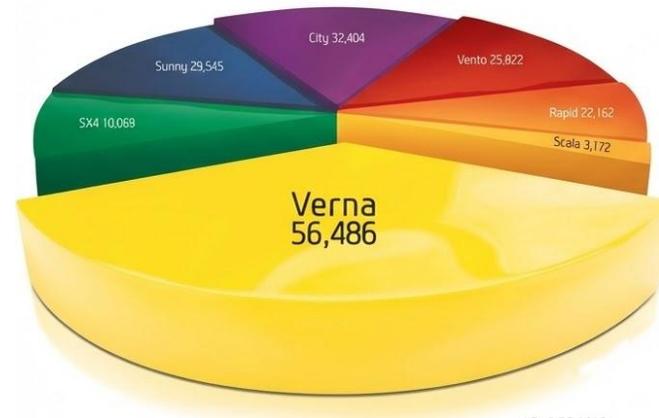
High Data Ink Ratio

Chartjunk

Visual elements that distract rather than inform:

✓ **3D Effects:** Adds fake depth that distorts data points.

✓ **Clipart/Icons:** Can clutter the workspace and increase cognitive load.

✓ **Excessive Decoration:** Patterned fills or shadows that don't represent data.

⚠ "Decoration is acceptable only if it reinforces the message without distortion."
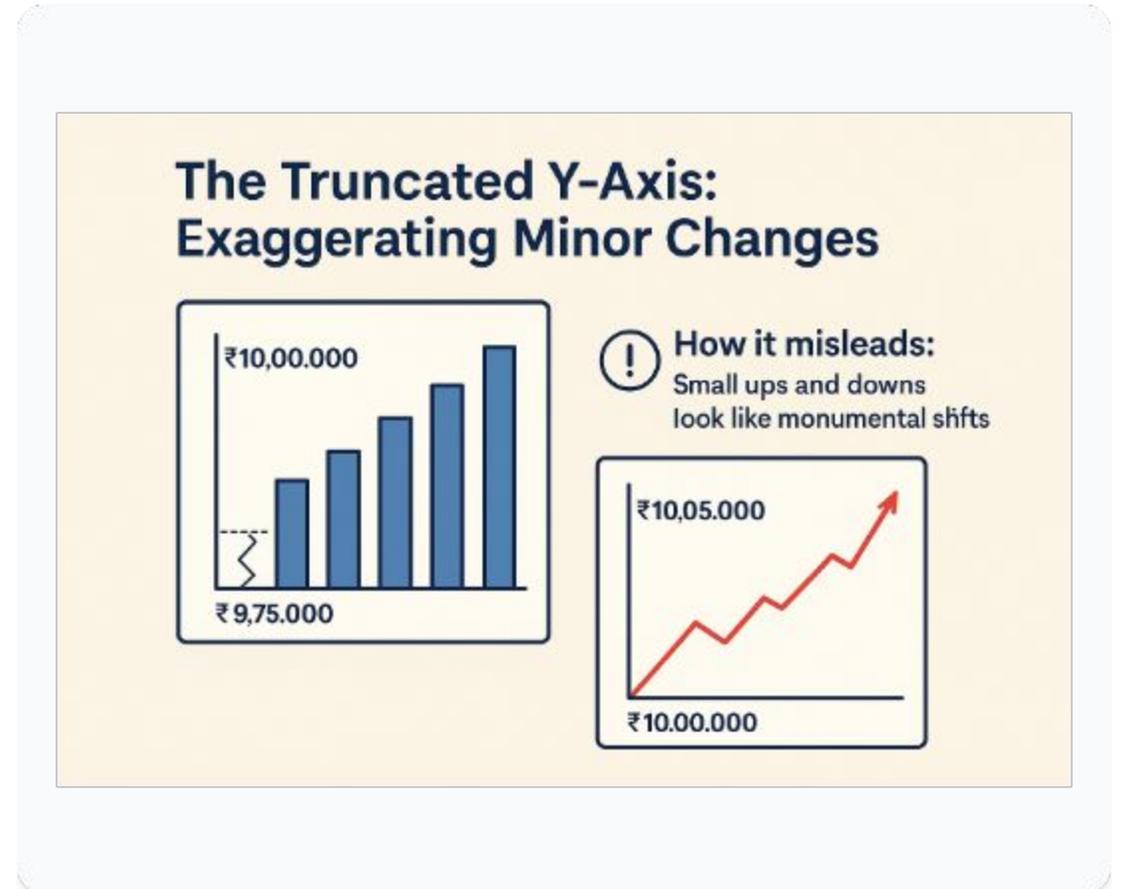
Misleading Visuals: Truncated Y-Axis

The Power of the Scale

A chart can be technically correct (data-wise)

but visually dishonest.

- ✓ **Truncated Axes:** Starting the Y-axis above

  zero can exaggerate small differences.

- ✓ **Inconsistent Scales:** Changing the interval

  size across an axis.

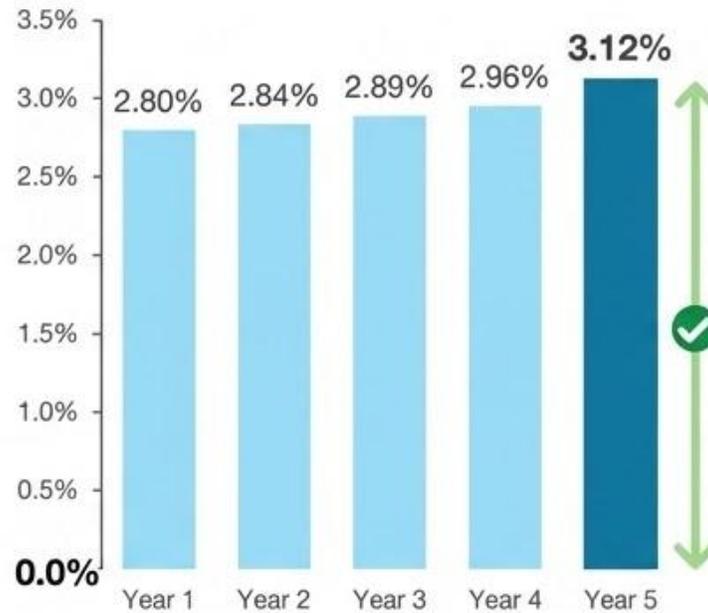- ✓ **Ethical Responsibility:** Honesty over

  persuasion.

When bars lie: Truncated y-axis on bar charts

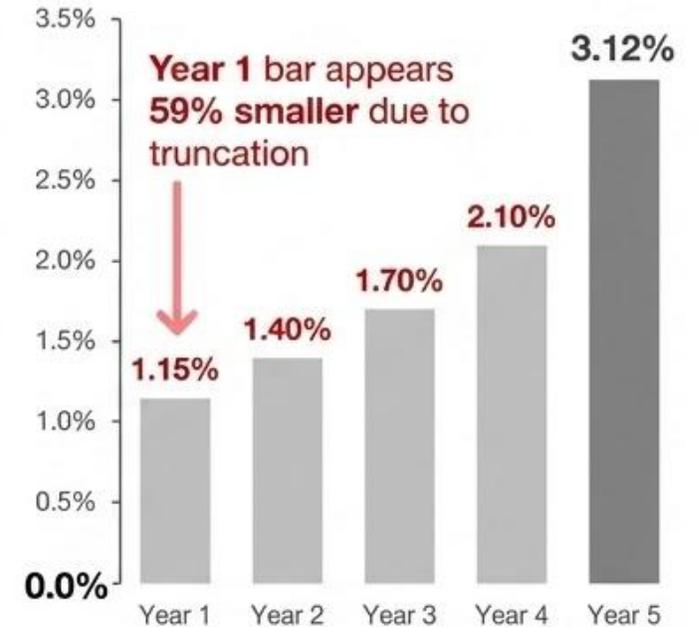## Visually exaggerated
with truncated baseline

Bar values: 2.80%, 2.84%, 2.89%, 2.96%, 3.12%
(Year 1 – Year 5)
Y-axis: 2.6% to 3.2%

❌
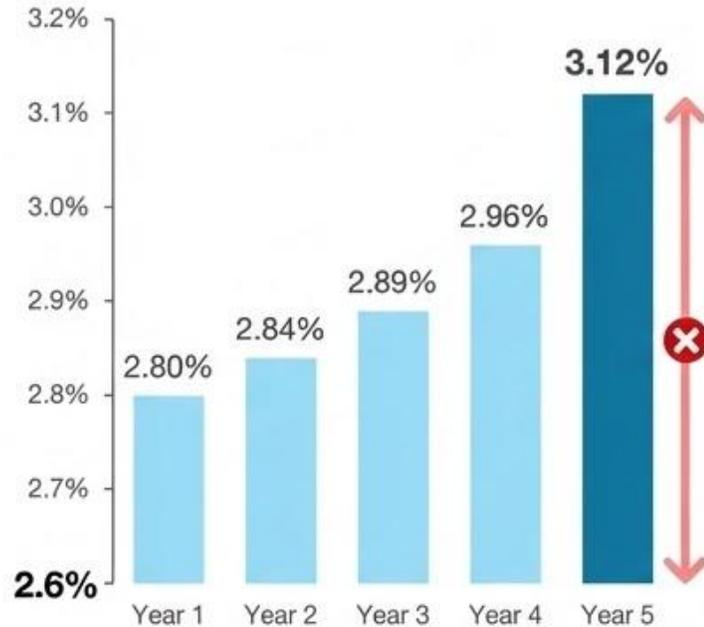
⚠️ Excel default chart with truncated y-axis.

Accurate representation
with zero baseline

Bar values: 2.80%, 2.84%, 2.89%, 2.96%, 3.12%
(Year 1 – Year 5)
Y-axis: 0.0% to 3.5%

✅

✅ Adjusted to true scale with a y-axis baseline that starts at zero.

Equivalent sizing
with zero baseline

Year 1 bar appears **59% smaller** due to truncation

Bar values: 1.15%, 1.40%, 1.70%, 2.10%, 3.12%
(Year 1 – Year 5)
Y-axis: 0.0% to 3.5%

When you size the bars like the truncated version, the distortion becomes clear.

*Example from *Effective Data Storytelling Masterclass*

Effectivedatastorytelling.com

Color Usage Principles

✅ **Distinguish:** Use different hues for distinct categories.

✅ **Highlight:** Use a bright accent color for key data against a neutral gray background.

✅ **Accessibility:** Always consider colorblind-friendly palettes (e.g., ColorBrew).

Rule of Thumb:

If a color doesn't represent a specific category or value, it shouldn't be there.

Protanopia: Loss of Red Cone Test

...Cyan Data Story told ...rmal Color Vision

Deuteranopia: Loss of Green Cone Test

The Yellow-Purple Contrast Data Story told via Protanopia or Deuteranopia

Tritanopia: Loss...

The Turquoi... Data Story tol...
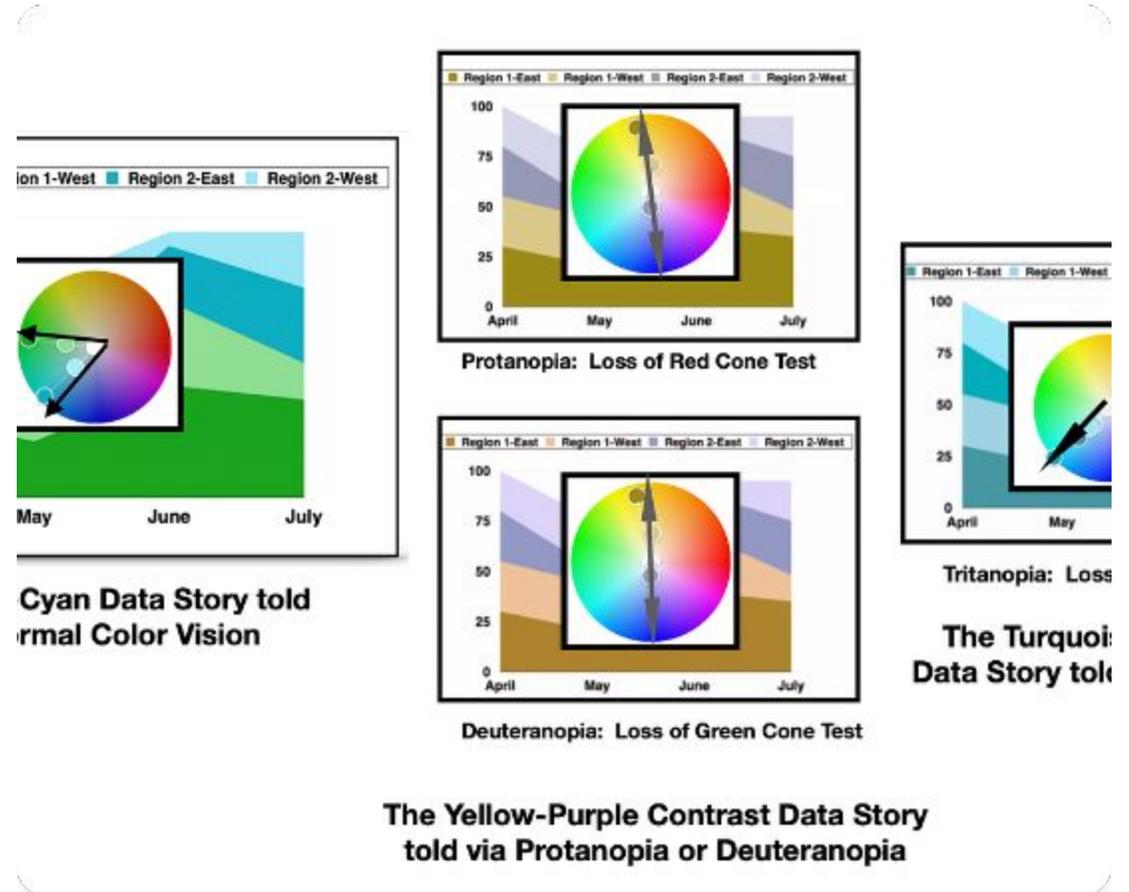
Ethical Responsibility

Integrity in Design:

- ✓ Visualizations influence critical decisions; honesty must prevail over persuasion.

- ✓ Designers have an ethical responsibility to avoid accidental or intentional deception.

- ✓ Transparency in data sources and transformation methods is paramount.
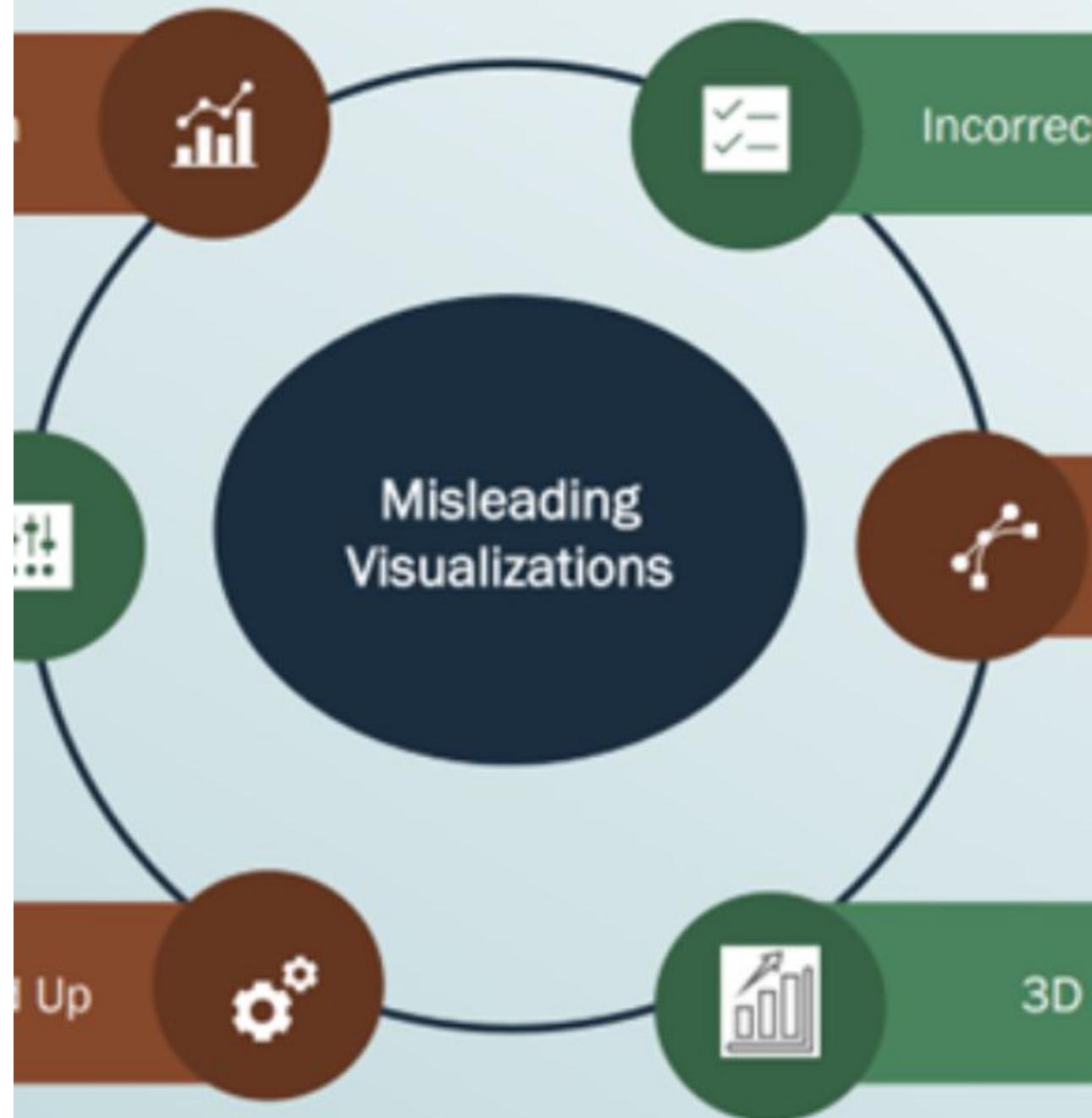
Choosing the Right Chart

Let the data question guide your chart selection.

Trends

Use line charts to show how data changes continuously over time.

Comparison

Use bar charts for comparing values across different categories.

Relationship

Use scatter plots to identify correlations between two variables.

Common Chart Misuse

Avoid these common pitfalls that increase confusion:

- ✓ **Overloaded Pies:** Pie charts with too many slices are impossible to read accurately.

- ✓ **Categorical Lines:** Using line charts for non-sequential, categorical data.

- ✓ **Inappropriate Scale:** Using log scales when linear scales are more intuitive.

Consistency and Simplicity

✓ **Consistent Scales:** Maintain the same axis ranges across related charts for easy comparison.

✓ **Unified Color Palette:** Ensure colors have consistent meaning throughout your presentation.

✓ **Single Message:** Each chart should aim to communicate one clear insight effectively.

✓ **Minimalist Labeling:** Remove redundant information that doesn't add value to the message.

> *"Simplicity is the ultimate sophistication in data storytelling."*

2013 MLS Salaries
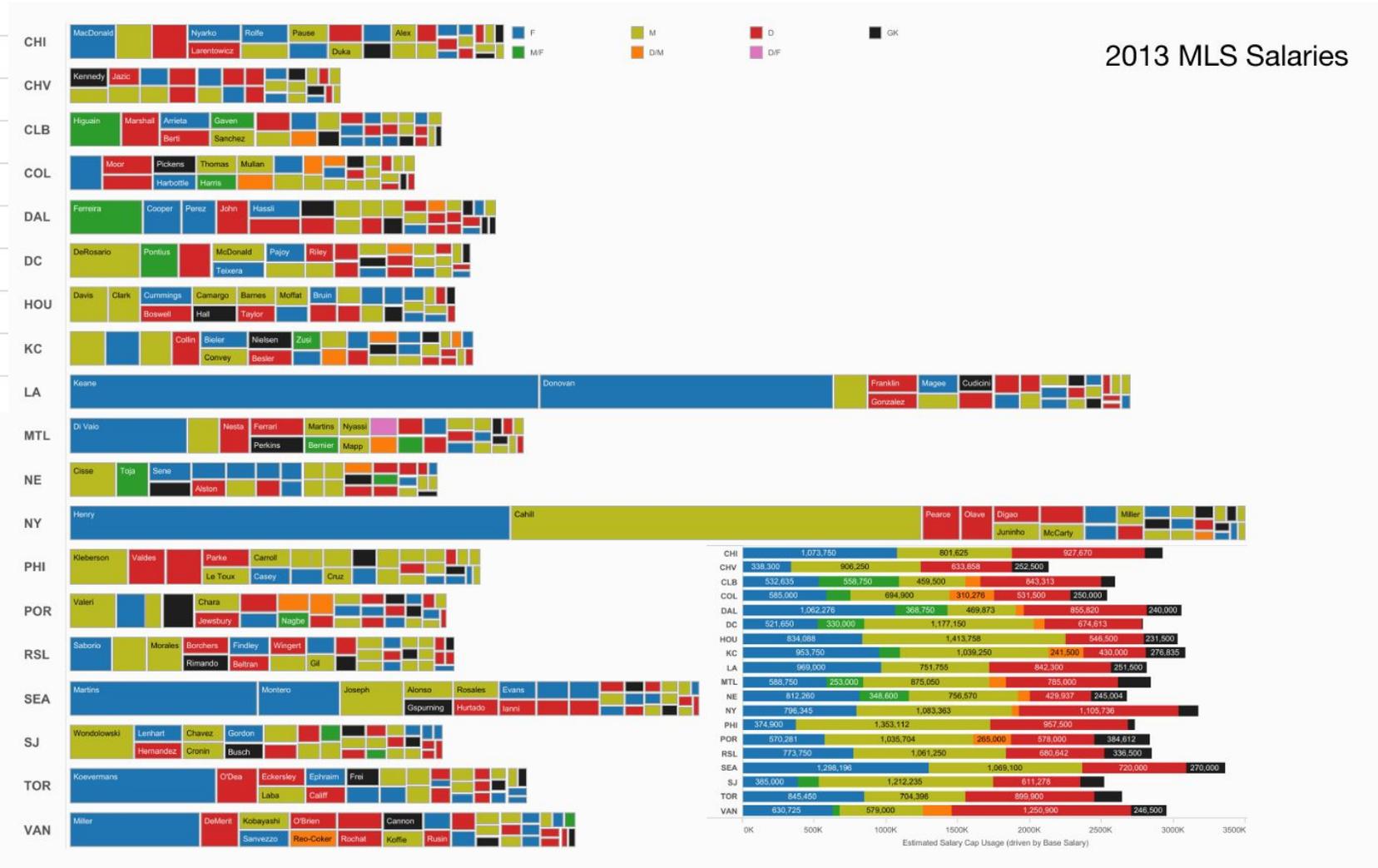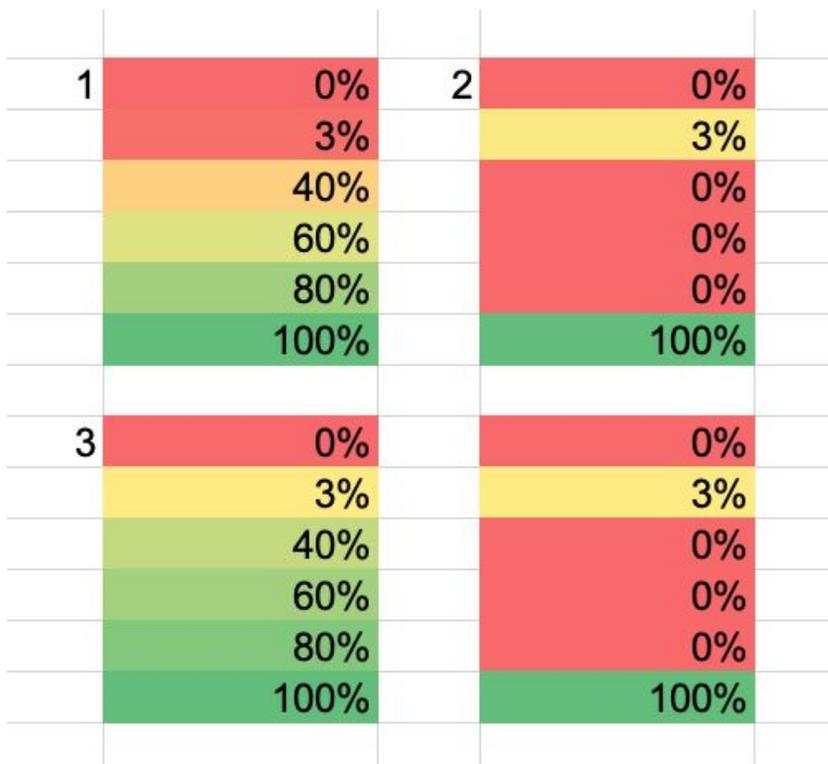
Color Usage Principles

- ✓ **Distinguish Categories:** Use hue to separate different groups of data.

- ✓ **Highlight Key Data:** Use high contrast colors to draw attention to specific data points.

- ✓ **Sequential Meaning:** Use saturation or lightness gradients for quantitative ranges.

- ✓ **Avoid Overuse:** A rainbow of colors often distracts rather than clarifies.
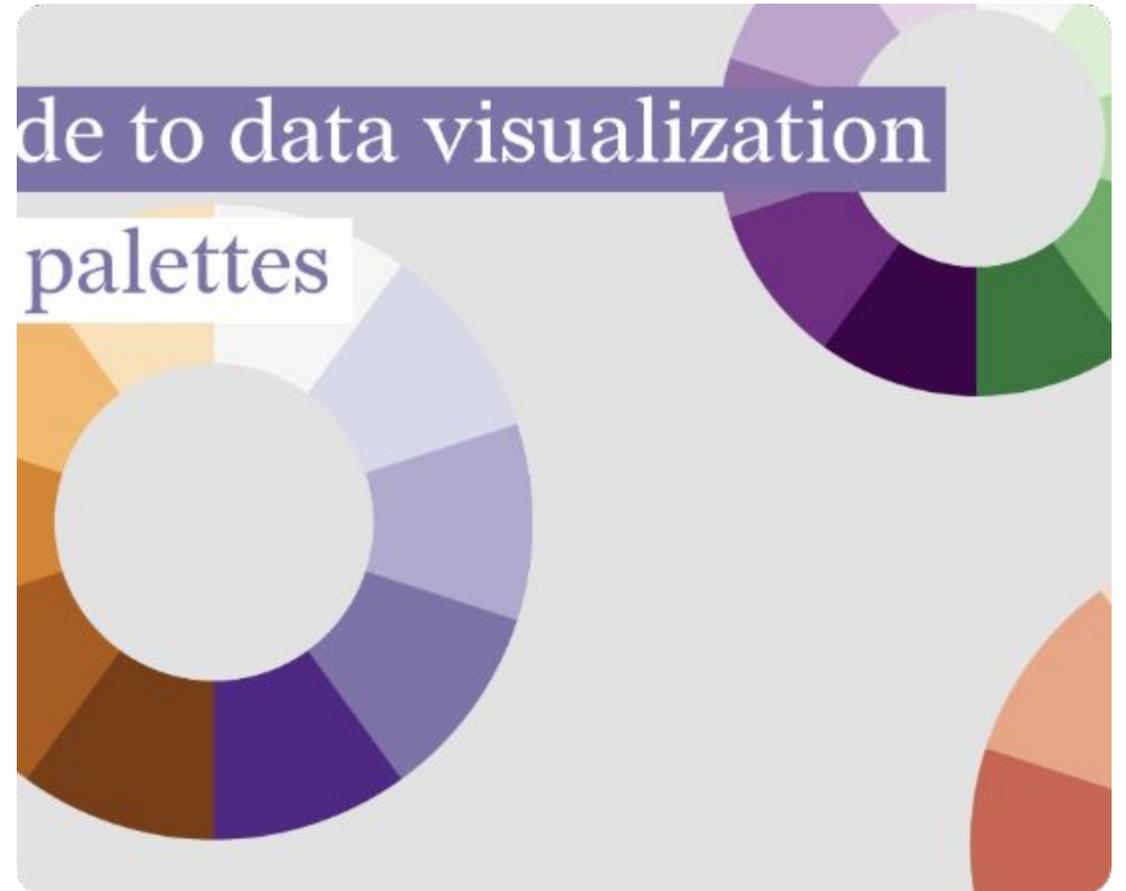
Titles and Labels

Effective Titles

A good title explains the main insight, not just the variables. It should tell the audience what to look for.
Example: "Q4 Revenue Grew by 15%" instead of "Quarterly Sales."
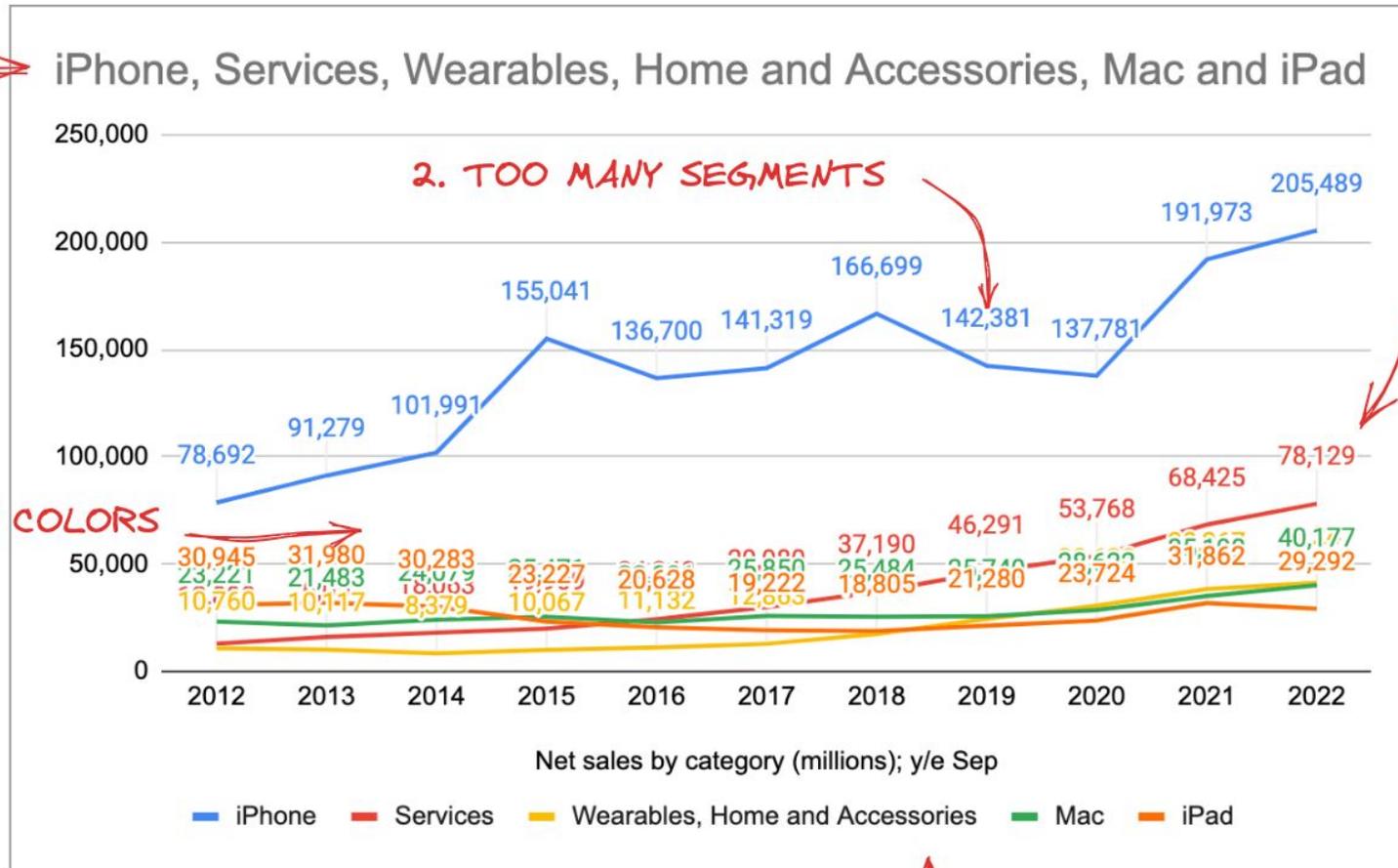
Clear Labels

Labels should be legible and include units of measurement. Avoid vertical or diagonal text whenever possible.
Tip: Direct labeling on lines is often better than a separate legend.

BAD CHART FORMATTING
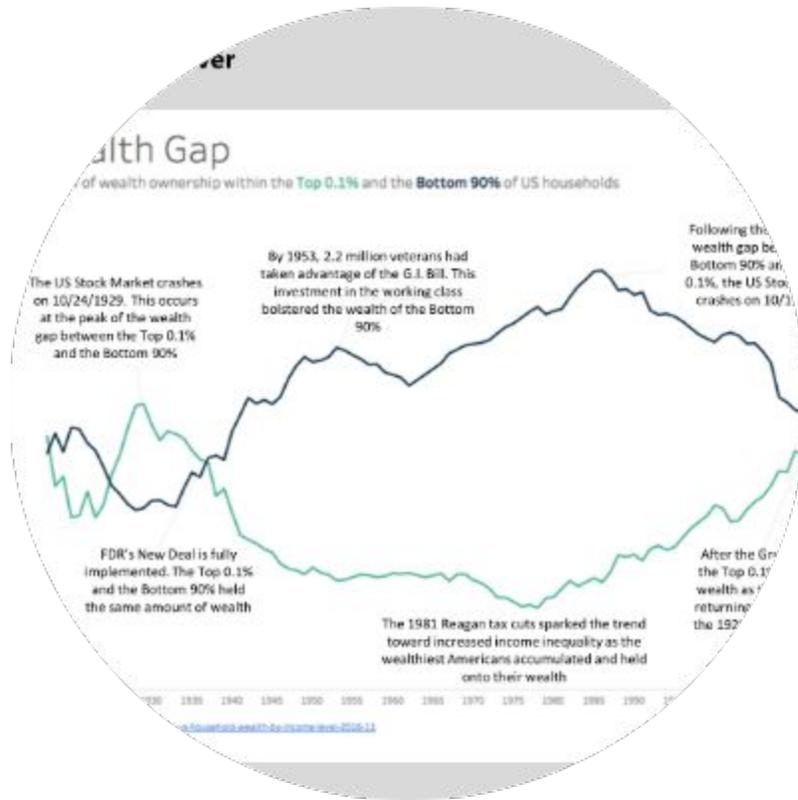
1. NON-DESCRIPTIVE TITLES

4. DATA OVERLOAD

iPhone, Services, Wearables, Home and Accessories, Mac and iPad

2. TOO MANY SEGMENTS

3. RAINBOW COLORS

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
iPhone	78,692	91,279	101,991	155,041	136,700	141,319	166,699	142,381	137,781	191,973	205,489
Services	30,945	31,980	30,283	23,227		25,850	37,190	46,291	53,768	68,425	78,129
Mac	23,221	21,483		23,227	20,628	25,484		21,280	23,724		40,177
Wearables	18,063		8,379	10,067	11,132	19,222	18,805			31,862	29,292
iPad	10,760	10,117				12,803			23,724		

Net sales by category (millions); y/e Sep

— iPhone — Services — Wearables, Home and Accessories — Mac — iPad
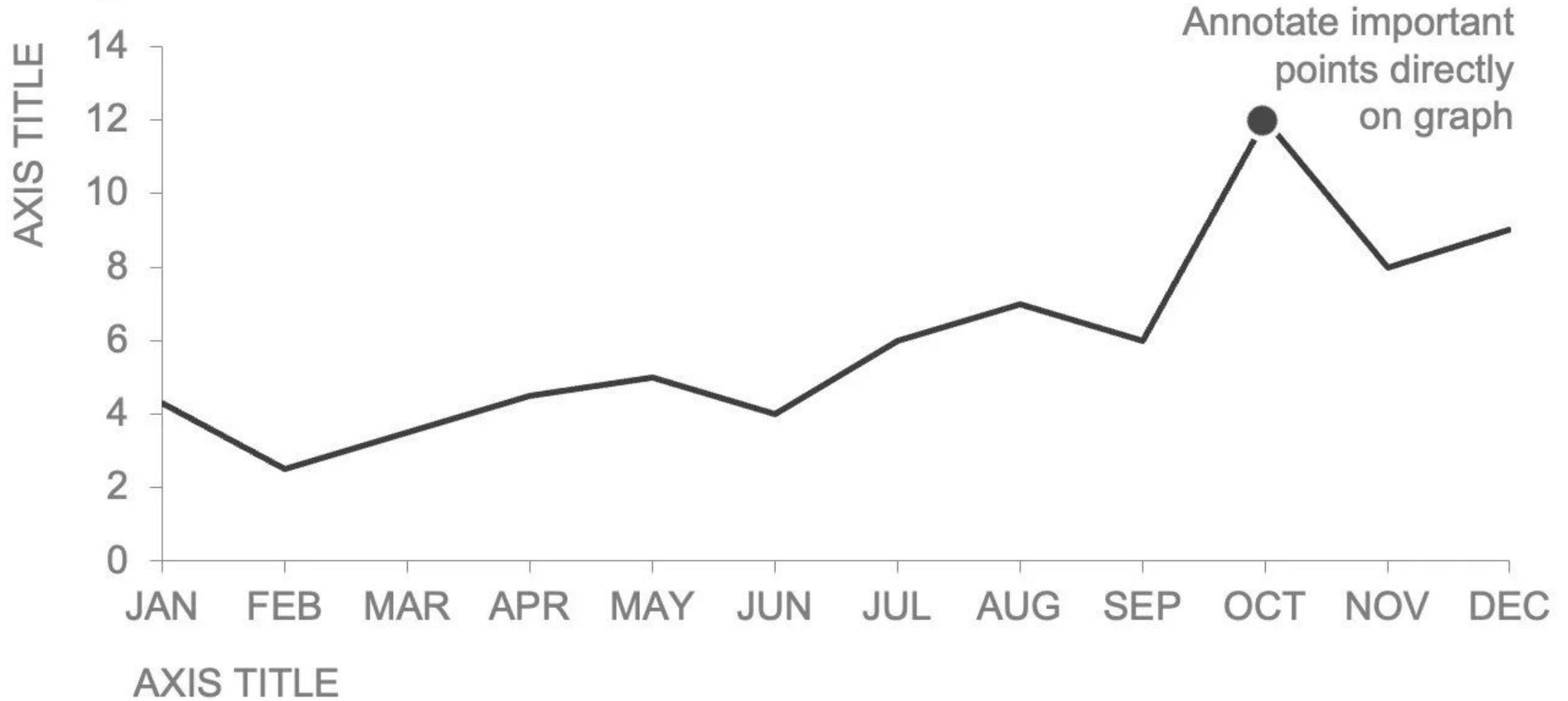
5. INDIRECT LEGENDS

Using Annotations

Guide the Audience

✓ **Callouts:** Use text to highlight significant spikes or dips.

✓ **Explanations:** Clarify unusual values directly on the chart.

✓ **Avoid Clutter:** Annotate only the most critical points to maintain focus.

Graph title

Annotate important points directly on graph

Chapter Summary

Perception

Align visuals with how the human brain processes information naturally.

Design

Maximize data-ink and minimize chartjunk for maximum clarity.

Ethics

Commit to accuracy and simplicity to ensure honest communication.
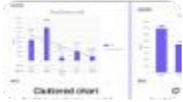
What's Next?

Chapter 4: Data Visualization Techniques

- Types of data and visualization methods

- Charts and graphs

- Infographics

Transitioning from theoretical principles to technical implementation.

Image Sources

https://ajelix.com/wp-content/uploads/2023/08/clean-chart-vs-cluttered-chart_2.webp
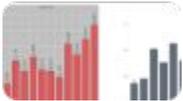
Source: ajelix.com

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Source: deliveringdataanalytics.com

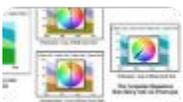
https://miro.medium.com/v2/resize:fit:1024/0*-IFUms8tyW6y8iA7.png

Source: bharathraj25.medium.com

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Source: www.helicalinsight.com

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Image Sources

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