Perception & Color

Designing charts for the human visual system — then learning how to *read* charts defensibly.

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Today's Plan

01 · PERCEPTION
How people see charts
Preattentive cues, grouping, and limits.

02 · COLOR
Mapping colors to data
Palette types + accessibility basics.

03 · CHART READING
Spot misleading encodings
Pitfalls that break trust.

04 · PRACTICE
Audit + redesign
A workflow you can repeat.

Learning Outcomes

PERCEPTION

Choose channels that humans compare well

Position and length beat area and angle.

COLOR

Match palette type to data type

Qualitative vs sequential vs diverging.

ACCESSIBILITY

Design beyond "color only"

Contrast + redundancy + clear labeling.

CHART READING

Audit charts for misleading choices
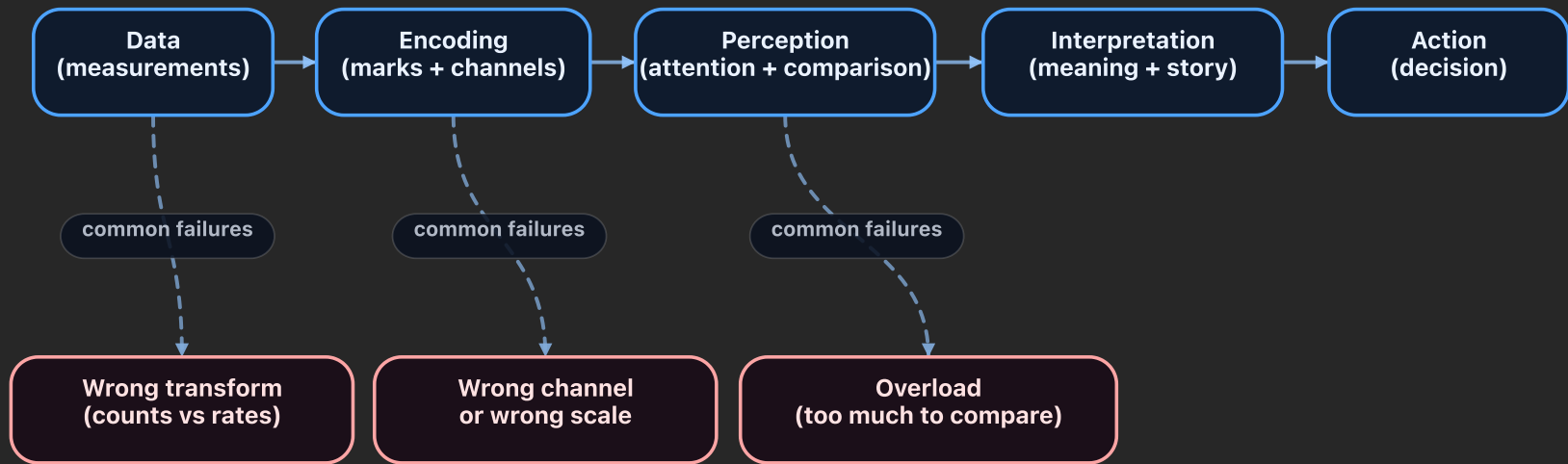
Axes, baselines, scales, and aggregation.

Perception is the interface

The chart is not the message. The *viewer's perception* is.

The Visualization Pipeline (Where Errors Enter)

Data (measurements) → Encoding (marks + channels) → Perception (attention + comparison) → Interpretation (meaning + story) → Action (decision)

common failures → Wrong transform (counts vs rates)

common failures → Wrong channel or wrong scale

common failures → Overload (too much to compare)

Preattentive Cues (What the Eye Sees "Immediately")

FAST COMPARISONS
Position, length, slope
Best for "how much" and trends.

FAST GROUPING
Hue, shape, enclosure
Best for "which group?"

More precise → less precise
(for magnitude)

Position (common scale) → Length → Angle / Area → Color lightness → Hue (for groups)

Use hue for grouping,
not "how much"
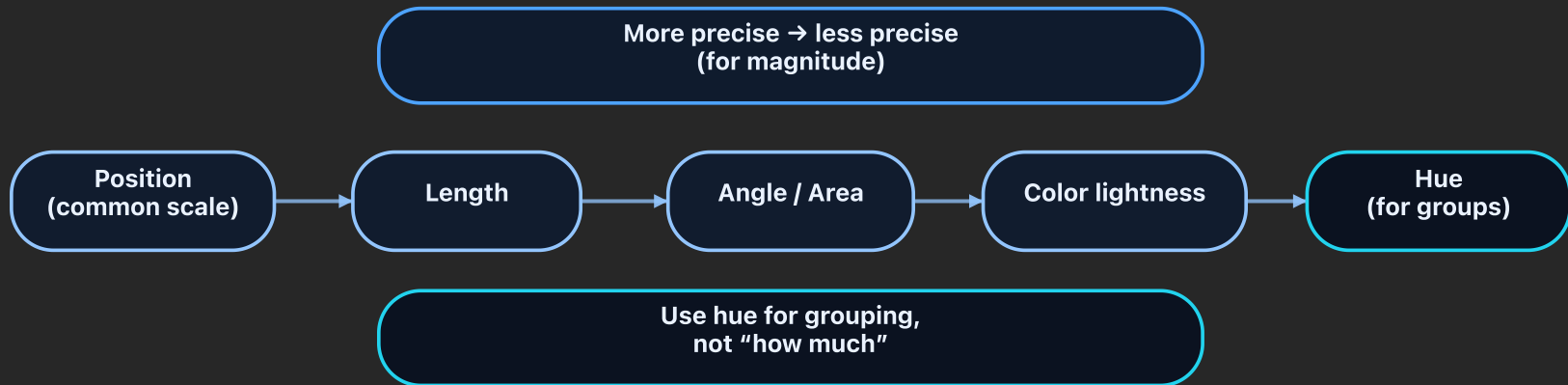
Attention + Working Memory (Why "Too Much" Breaks Charts)

ATTENTION
Selective
Viewers don't read everything.

MEMORY
Limited
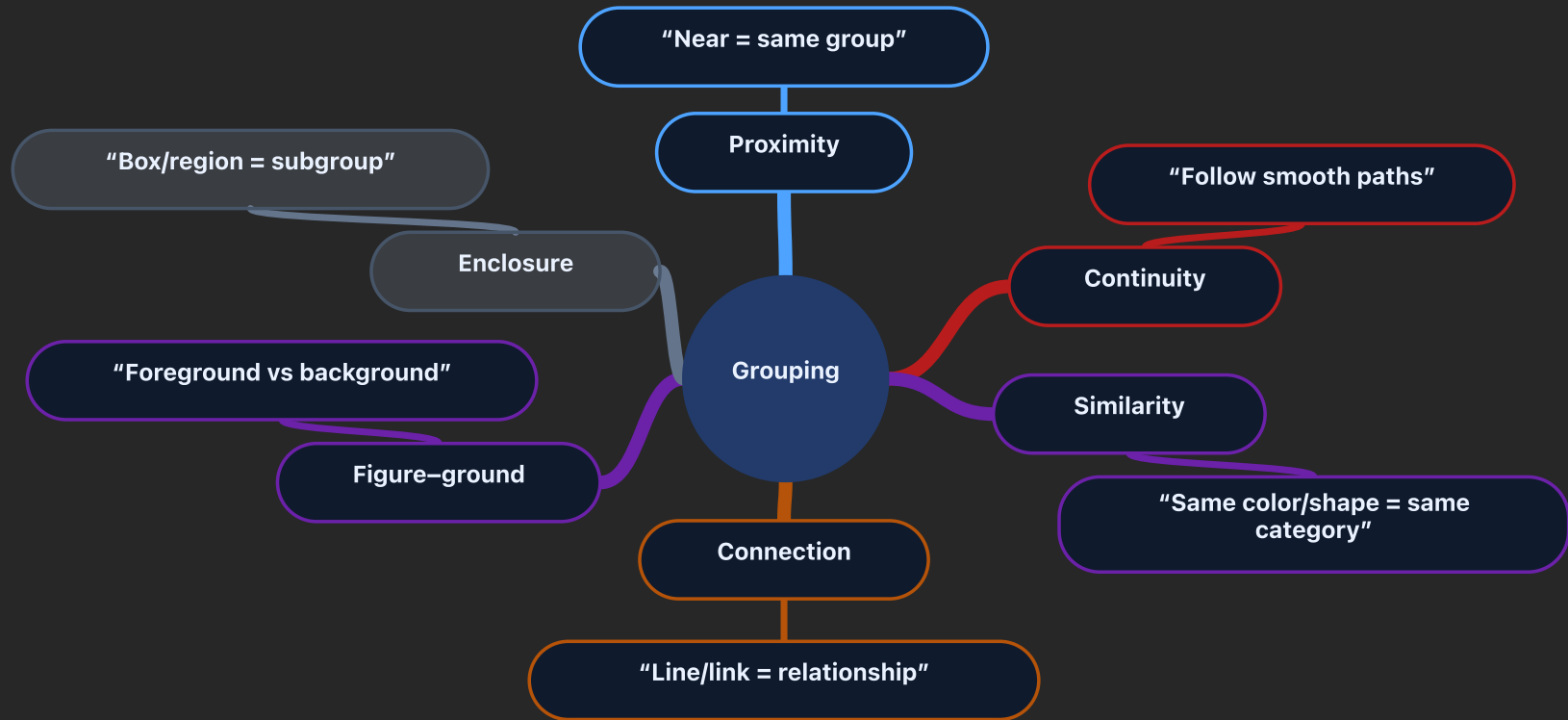Don't force "legend hunting."

COMPARISON
Fragile
Use shared scales + alignment.

RULE OF THUMB
If your chart needs a paragraph to explain how to read it, redesign the chart.

Gestalt Principles (How Viewers Group Marks)

"Near = same group"

Proximity

"Box/region = subgroup"

Enclosure

"Follow smooth paths"

Continuity

"Foreground vs background"

Grouping

Similarity

Figure–ground

"Same color/shape = same category"

Connection

"Line/link = relationship"

Proximity: Grouping Without Extra Ink
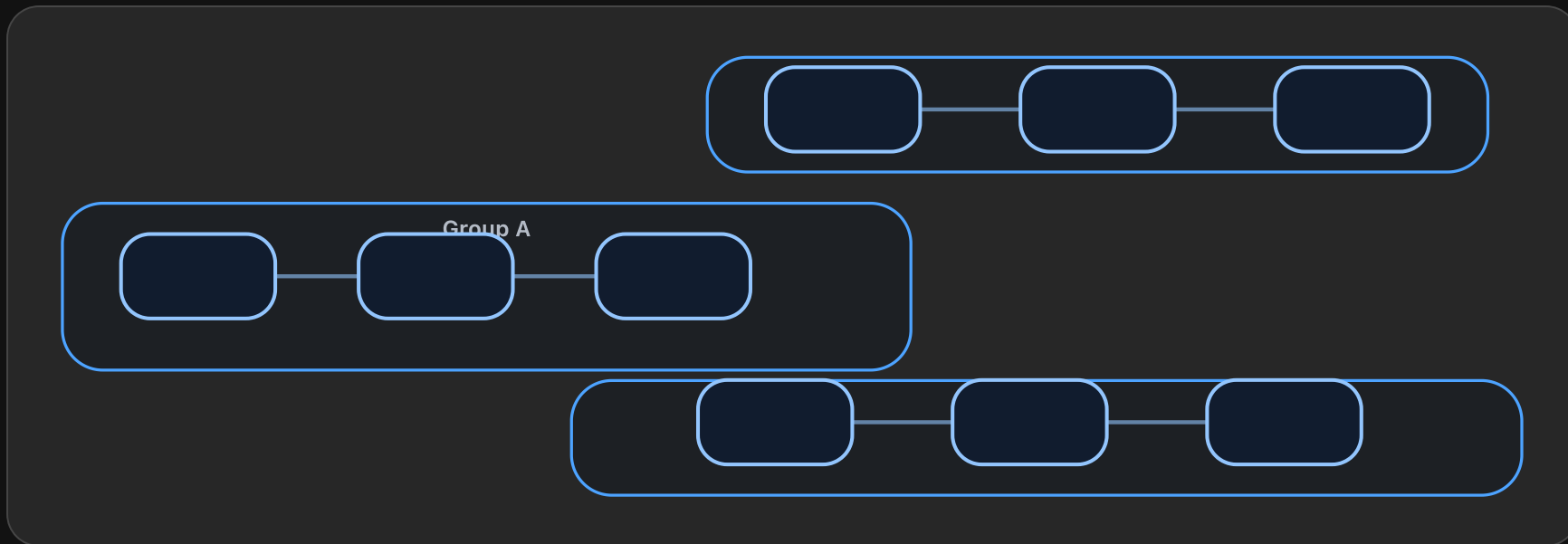
Group A

DESIGN MOVE

Use spacing and faceting to group — before adding more colors.

Similarity: When Color Creates Categories

Category A	Category A	Category A
Category B	Category B	
Category C	Category C	
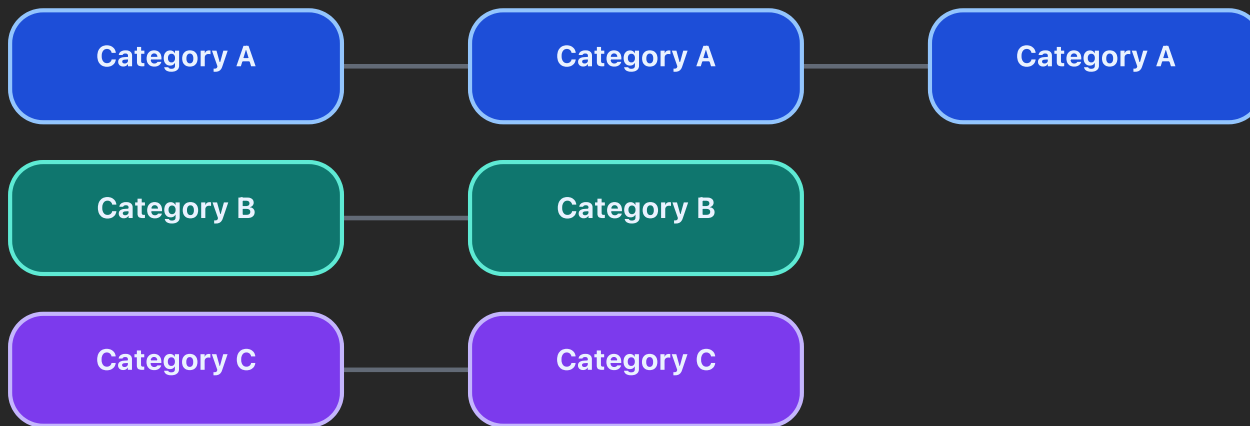
USE SIMILARITY FOR

Grouping, not magnitude

Hue answers "which group?"

COMMON MISTAKE

Hue implies "how much"

Prefer lightness for ordered data.

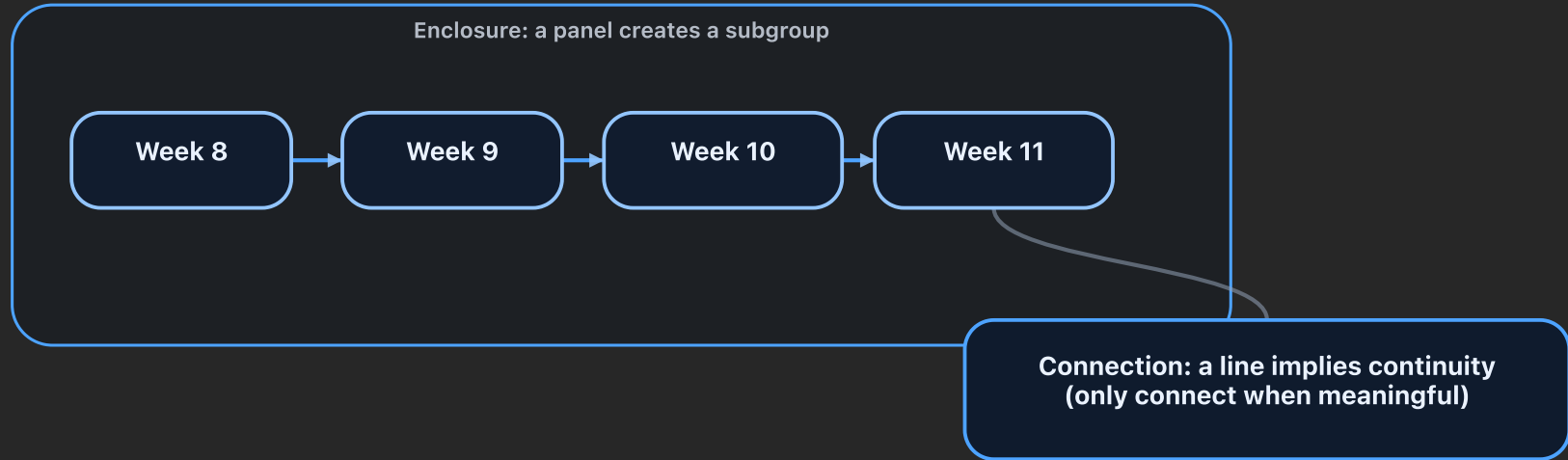# Connection + Enclosure (When Lines and Boxes Mean Something)

Enclosure: a panel creates a subgroup

Week 8 → Week 9 → Week 10 → Week 11

Connection: a line implies continuity
(only connect when meaningful)

Visual Hierarchy (Make the Intended Reading Obvious)

HIERARCHY RECIPE
1 headline + 1 takeaway

State what to look for before showing details.

REDUCE NOISE
De-emphasize non-data ink

Light gridlines, fewer ticks, direct labels.

**Headline:
what matters** → **Key marks
highlighted** → **Details
(background context)**

Mapping Color to data

Color is powerful — and easy to misuse.

Color Has Three Useful Dimensions

Hue (which color)	Lightness (how bright/dark)	Chroma / Saturation (how intense)
↓	↓	↓
Best for categories	Best for ordered magnitude	Best for emphasis, not scale
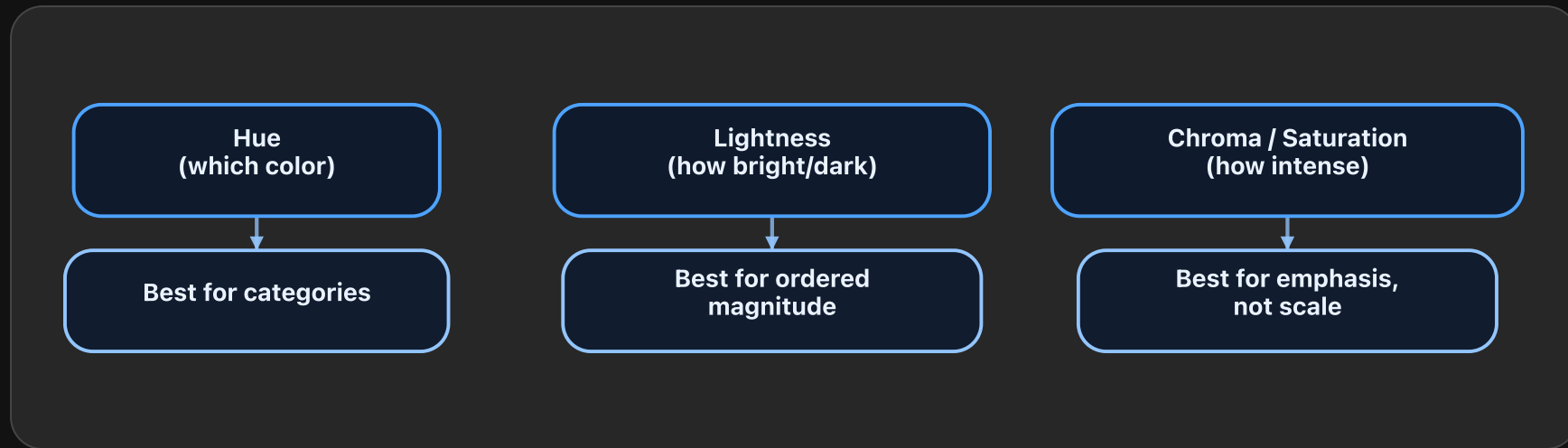
KEY MESSAGE

Hue answers "which group?" Lightness answers "how much?"

Three Palette Types You Should Know

Qualitative
Categories

Blue   Sky   Green   Orange   Vermillion   Purple

Sequential
Low → High

0   50   100

Diverging
Below ↔ Above

−1.0   0.0   1.0

Match Color to Data Type + Task

```
What is the                    Categorical    →    Use distinct hues    →    Avoid:
variable type?                                                                too many categories
                                                                              → legend overload

                               Ordered /       →    Sequential          →    Avoid:
                               Quantitative         lightness ramp           rainbow / nonuniform
                                                                              scales

                               Baseline        →    Diverging scale     →    Avoid:
                               difference           centered at              midpoint not meaningful
                                                     0/baseline
```
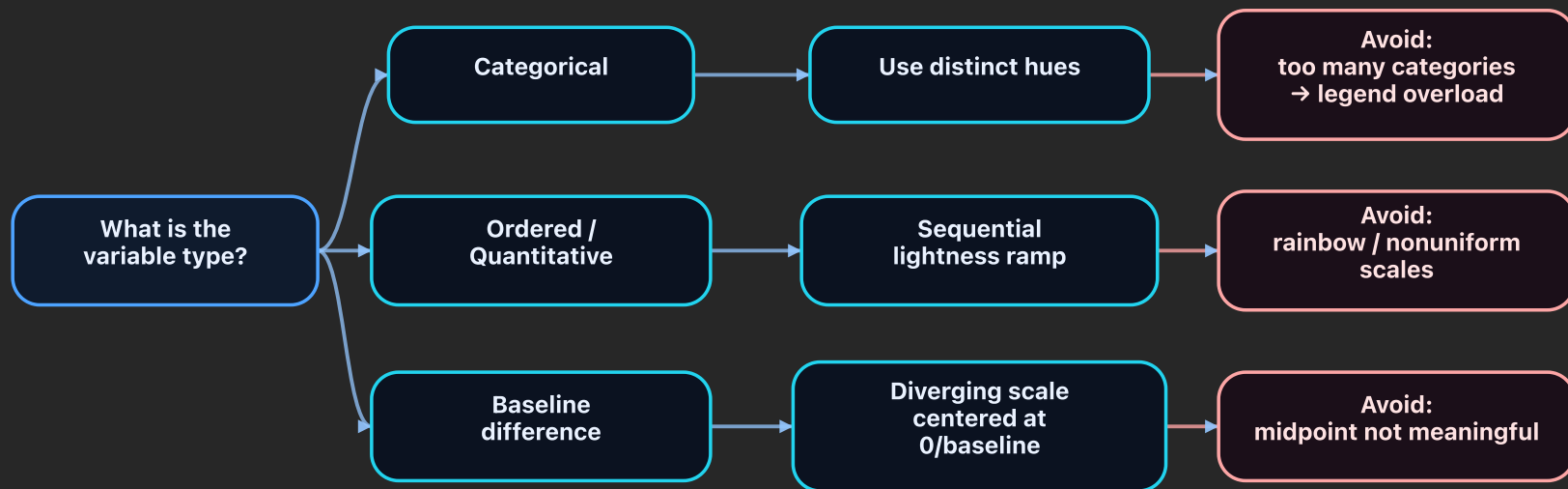
Qualitative Palettes: Practical Rules

HOW MANY?

≤ 6 categories

Beyond that, use facets, grouping, or interaction.

HOW TO LABEL?

Direct labels > legends

Legends are fine, but don't make them mandatory.

HOW TO HIGHLIGHT?

One accent

Gray everything else, highlight the point of interest.

CONSISTENCY

Same color = same meaning

Across slides, charts, and the whole project.

A Colorblind-Safer Qualitative Palette (Example)

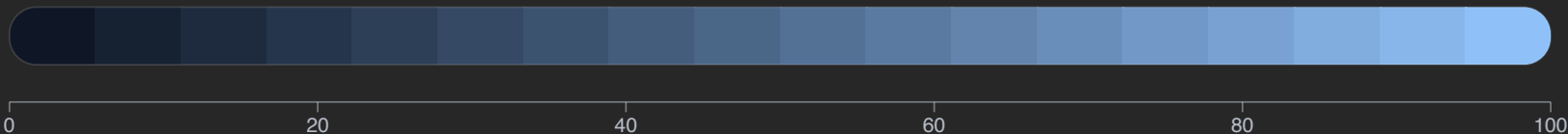| Blue | Sky | Green | Orange | Vermillion | Purple | Yellow | Gray |

USE IT LIKE THIS

Pick 4–6 colors + keep one neutral for baseline/context.

Sequential Scales (Magnitude: Low → High)

Lightness ramp (ordered magnitude)

0   20   40   60   80   100

Example: same values as a heatmap (higher = lighter)

GOOD SCALE PROPERTY

Lightness increases smoothly

So order is visible even in grayscale.
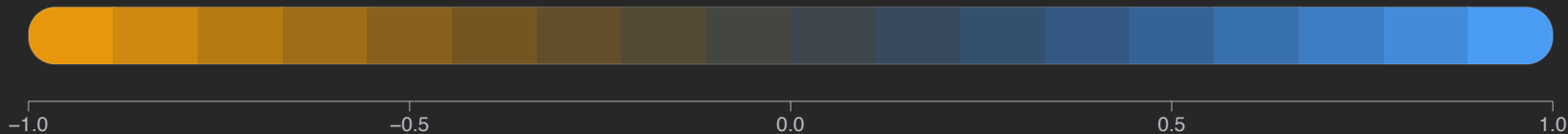
COMMON FAILURE

Hue changes create false boundaries

Viewers "see" edges that aren't real.

Diverging Scales (Difference Around a Baseline)

Centered midpoint (baseline = 0)

−1.0   −0.5   0.0   0.5   1.0

Example: negative vs positive differences around the baseline

CRITICAL REQUIREMENT

Only use diverging scales when the midpoint is meaningful (0, target, average).

The Rainbow Trap (Why It Misleads)

Rainbow-like
Creates false boundaries

Low   High
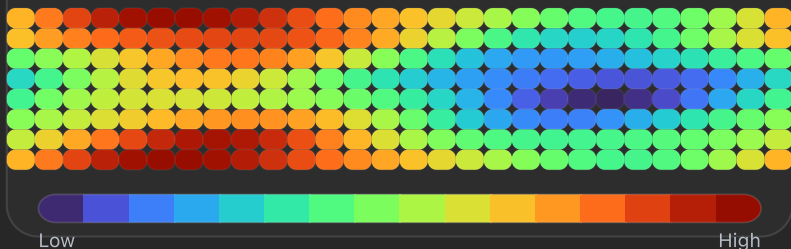
Perceptual
Order visible in lightness

Low   High
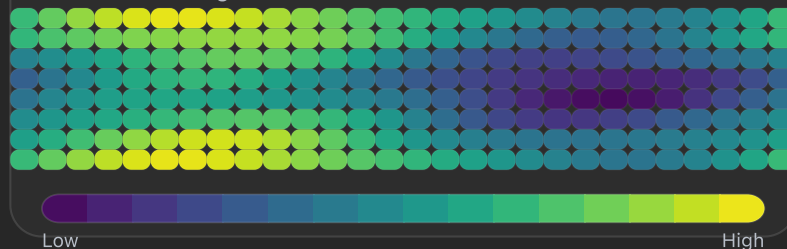
WHY IT MISLEADS

- Non-uniform perception: some hues "pop."
- False boundaries: hue edges look categorical.
- Not robust: breaks in grayscale and for CVD viewers.

DO INSTEAD

Use lightness ramps (and label them)

Sequential for magnitude; diverging only with a meaningful midpoint.

Include units + min/max (+ midpoint for diverging).

Color + Contrast on Dark Backgrounds
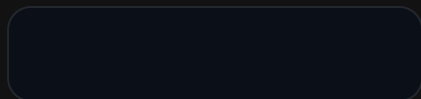
Background
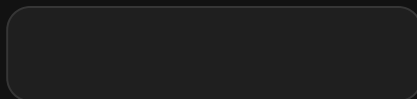
Surface

Accent

Text

CONTRAST FOR TEXT

Readable labels

Use off-white text; increase label size; avoid thin fonts.

CONTRAST FOR MARKS

Visible data ink

Thicker strokes; subtle gridlines; keep one strong accent.

PRACTICAL CHECKLIST

Neutrals + one accent · off-white text · thicker lines · subtle gridlines

Accessibility: CVD + Redundant Encoding

```
┌─────────────────────────────┐
│   Assume some viewers        │
│   cannot rely on red/green   │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│   Don't encode meaning       │
│   with color alone           │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│      Add redundancy          │
└─────────────────────────────┘
        │            │
   ┌────────────┐  ┌────────────────┐
   │ Direct labels│ │ Shape / markers │
   └────────────┘  └────────────────┘
   ┌────────────────┐  ┌──────────────────────┐
   │ Position / facets│ │ Check contrast + legend │
   └────────────────┘  └──────────────────────┘
```
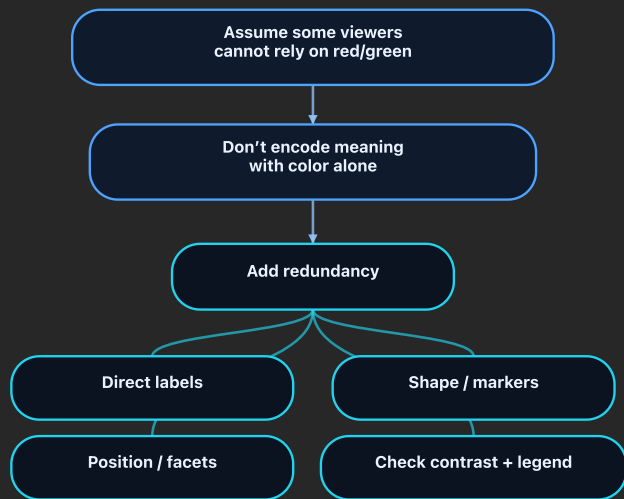
DO

Design for robustness

Prefer blue/orange contrasts; use lightness ramps for magnitude; label directly.

AVOID

Color-only meaning

Red/green-only signals; unlabeled scales; too many hues; required legend hunting.

Legends Done Right (Small Details, Big Trust)

GOOD LEGEND

Has units + ordering

Includes midpoint for diverging scales.

BAD LEGEND

Forces guesswork

Unlabeled bins, unclear min/max, missing "no data".

| -0.10 | -0.05 | 0 | +0.05 | +0.10 |

Missing Data ≠ Zero (A Common Interpretation Bug)

```
                    ┌─────────────────────┐
                    │   Is the value      │
                    │    missing?         │
                    └─────────────────────┘
                       Yes          No
              ┌──────────────────┐    ┌──────────────────┐
              │ Show as "No data"│    │ Encode the value │
              │(separate         │    │ with your scale  │
              │ color/pattern)   │    └──────────────────┘
              └──────────────────┘
                    avoid
              ┌──────────────────┐
              │ Do NOT map       │
              │ missing to 0     │
              └──────────────────┘
```
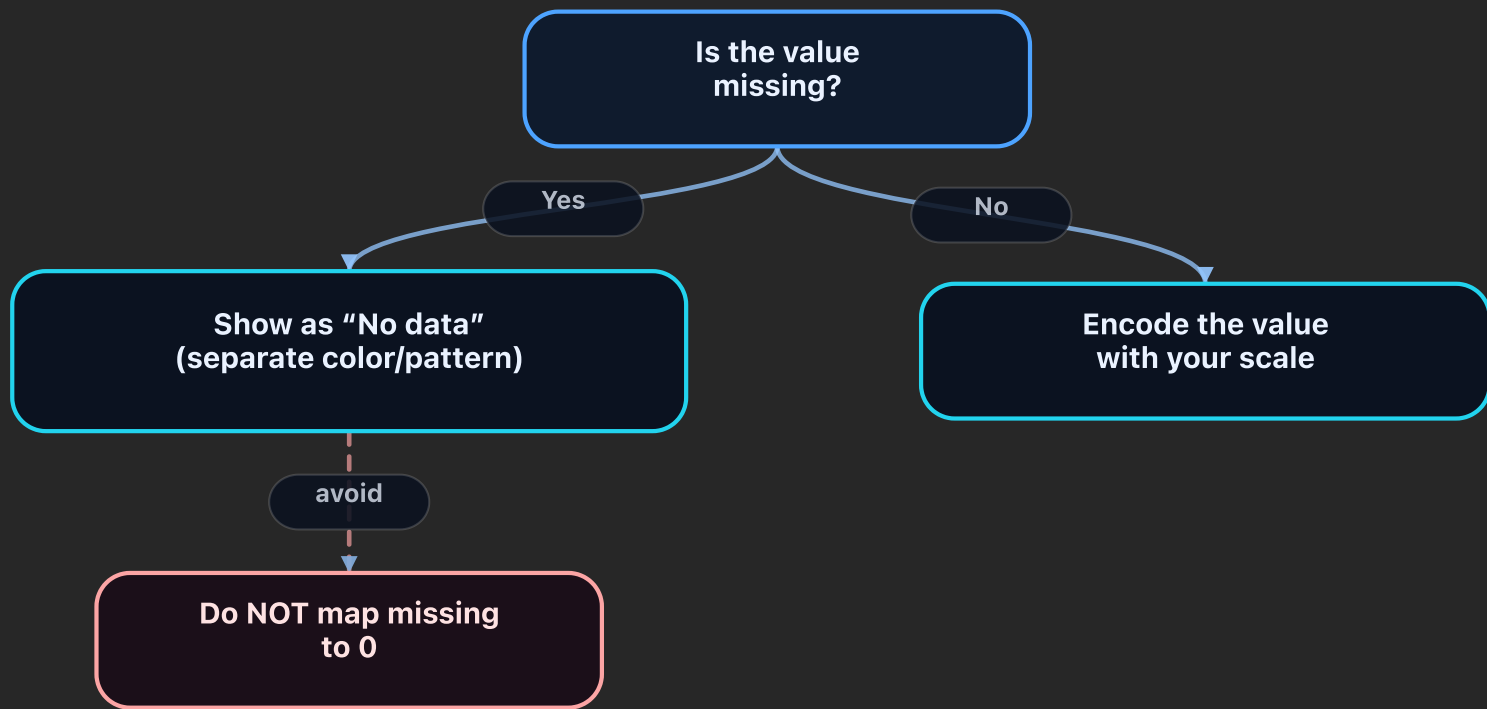
Color for Emphasis (Highlight, Don't Paint Everything)

BASELINE CONTEXT

Neutral

Gray or low-saturation colors.

FOCUS

One accent

Use the accent only where you want attention.

| Series A | Series B | Series C | Series D |

When Color Is the Wrong Tool

TOO MANY CATEGORIES

Use small multiples

Facets + consistent scales beat 12-color legends.

PRECISE COMPARISON

Use position

Dot plots and aligned bars are more accurate.

Do you need color?

Grouping a few categories

Precise magnitude comparison

Many categories

Yes: qualitative hues

Maybe not: use position

Avoid: facet or filter

Read charts like a skeptic

Trust the data, but verify the encoding.

An 8-Step Chart Reading Checklist

1. Title:
what claim is being made?

2. Data:
what is measured + missing?

3. Units:
counts vs rates vs %

4. Axes:
scale + baseline + truncation

5. Encoding:
position vs area vs color

6. Grouping:
aggregation + subgroups

7. Uncertainty:
sample size + variability

8. Conclusion:
does the chart support the claim?
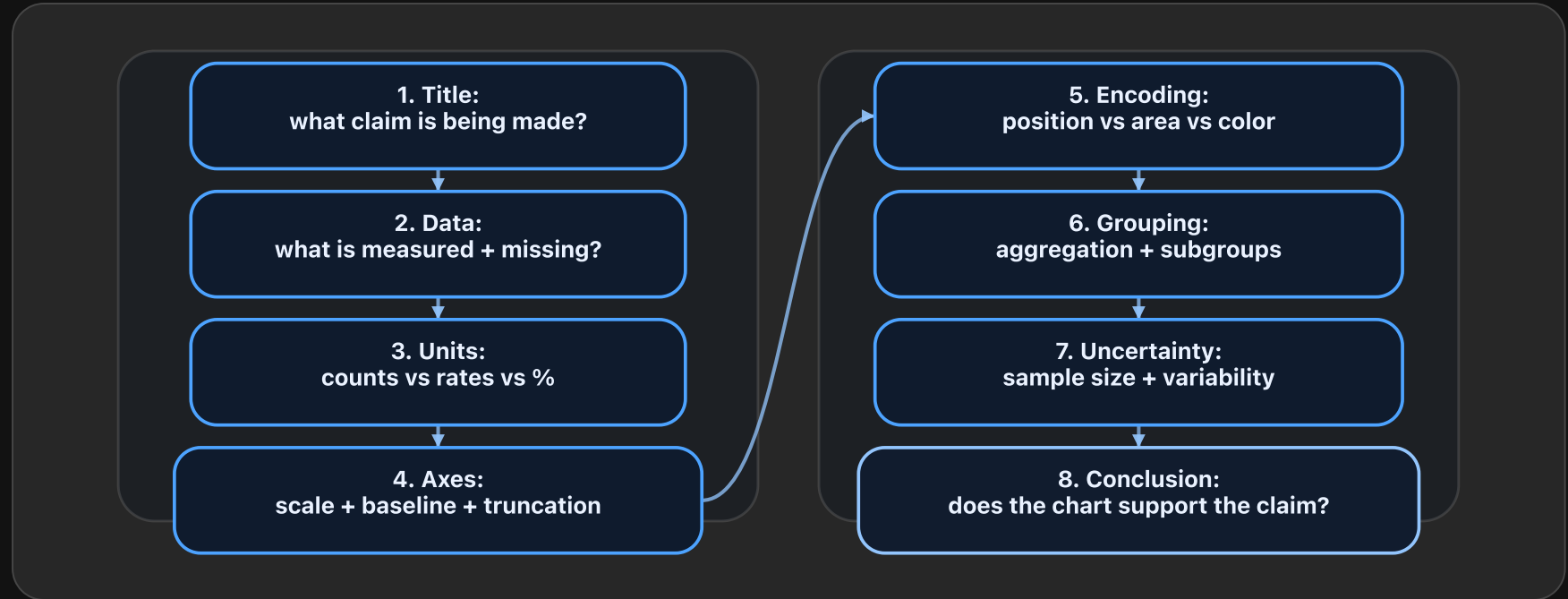
Pitfall: Truncated Axis (Especially for Bars)

WHY IT MISLEADS

Bars encode length from a baseline

If the baseline is not zero, the visual difference is inflated.

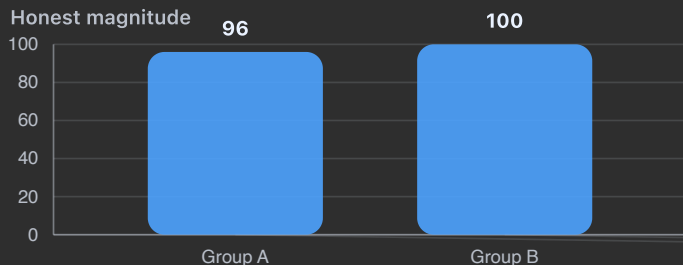WHEN ACCEPTABLE

Use dots/lines for nonzero baselines

Or clearly mark axis breaks and explain them.

Bar chart (baseline = 0)
Honest magnitude

Dot plot (zoomed axis)
OK to zoom for differences
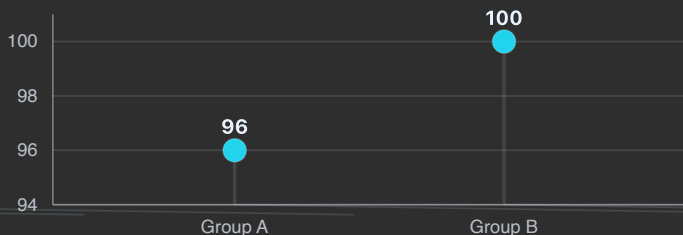
Pitfall: Dual Y-Axes (Two Stories in One Chart)

Right axis squeezed

Looks "correlated"

A (left axis)   B (right axis)

140 — — 45

120 — — 40

100 — — 35

— 30

2   4   6   8   10   12
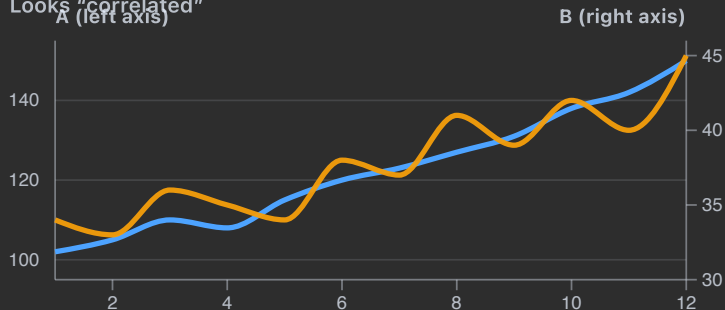
Right axis expanded

Looks "uncorrelated"

A (left axis)   B (right axis)

140 — — 80

120 — — 60

100 — — 40

— 20

— 0

2   4   6   8   10   12
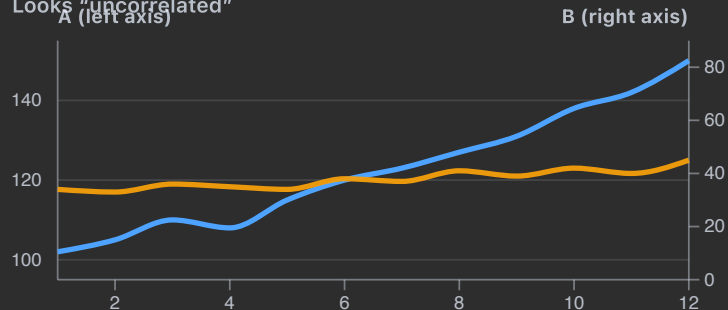
Pitfall: 3D and Perspective

PERCEPTION PROBLEM

3D turns accurate length comparisons into ambiguous area comparisons.

WHAT 3D ADDS

Decoration, not information

It makes the reading harder, not better.

PROFESSIONAL FIX

Use 2D with labels

Add annotation if you need emphasis.

Pitfall: Area Encodings (Bubbles, Pies, Stacked Areas)

Bubbles (area)
Hard to compare precisely

A: 10   B: 20   C: 40

Bars (length)
Aligned comparisons

A — 10
B — 20
C — 40

0   10   20   30   40
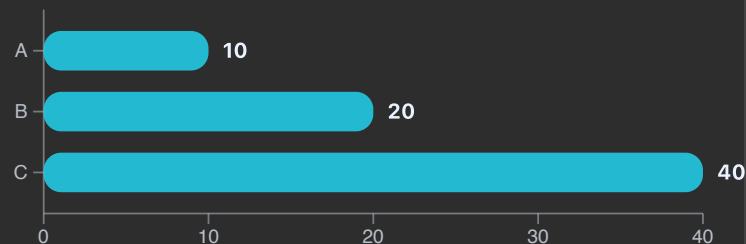
DESIGN GUIDANCE

If comparison matters, avoid area-only charts. Use aligned position instead.

Pitfall: "Average" Hides Distribution

Same average → **Very different spread** → **Different story for intervention**

READER MOVE

Ask: what is the distribution?

Outliers? bimodal? wide variance?

DESIGNER MOVE

Show uncertainty or spread

Box plots, intervals, or small multiples.

Pitfall: Counts vs Rates (Normalization Errors)

Comparing groups
with different sizes

↓

Counts can
mislead

↓

Use rates or
per-capita measures

↓

Always show
denominator (n)
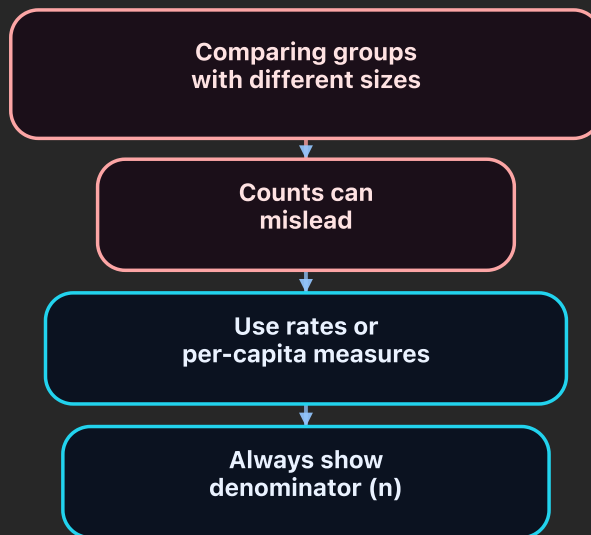
Pitfall: Binning and Scale Choices (Histograms, Heatmaps)

BINNING CHOICE

Controls what patterns appear

Too few bins hide structure; too many bins add noise.

SCALE CHOICE

Controls contrast

Linear vs log can change perceived differences.

```
Bins  →  Resolution  →  Perceived structure

Scale  →  Contrast  →  Perceived differences
```

Pitfall: Smoothing (It Can Hide or Invent Changes)

```
┌─────────────────────────┐        ┌─────────────────────────┐
│   Smoothing /           │        │   If you smooth         │
│   moving average        │        │                         │
└─────────────────────────┘        └─────────────────────────┘
            │                                   │
            ▼                                   ▼
┌─────────────────────────┐        ┌─────────────────────────┐
│   Can hide spikes and   │        │   Show raw data         │
│   shift timing          │        │   faintly               │
└─────────────────────────┘        └─────────────────────────┘
            │                                   │
            ▼                                   ▼
┌─────────────────────────┐        ┌─────────────────────────┐
│   Can invent trends     │        │   Label the window      │
│   if window is large    │        │   + method              │
└─────────────────────────┘        └─────────────────────────┘
```
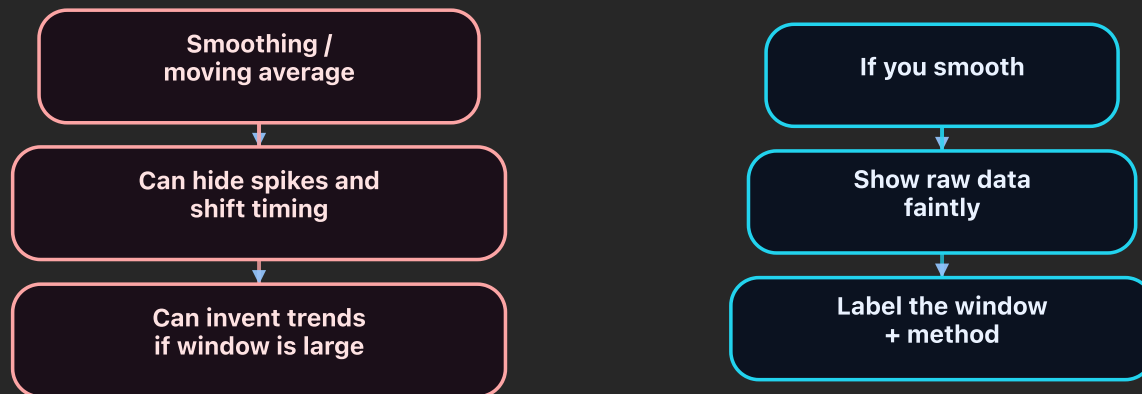
Pitfall: Uncertainty Missing (False Precision)

READER MINDSET
If you see a single line, ask: how variable is it?

ADD UNCERTAINTY
Intervals or distributions

Error bars, bands, dot plots, or box plots.

AT MINIMUM
Show sample size

So viewers can judge stability.

Pitfall: Cherry-Picked Time Windows

```
┌──────────────────┐      ┌──────────────────┐        ┌──────────────────┐
│   Pick a short   │ ───▶ │   Trend looks    │        │  Best practice   │
│      window      │      │    dramatic      │        │                  │
└──────────────────┘      └──────────────────┘        └──────────────────┘
                                                                │
                                                                ▼
┌──────────────────┐      ┌──────────────────┐        ┌──────────────────┐
│  Show context    │ ───▶ │  Trend becomes   │        │  Annotate why    │
│     window       │      │  interpretable   │        │ the window matters│
└──────────────────┘      └──────────────────┘        └──────────────────┘
```
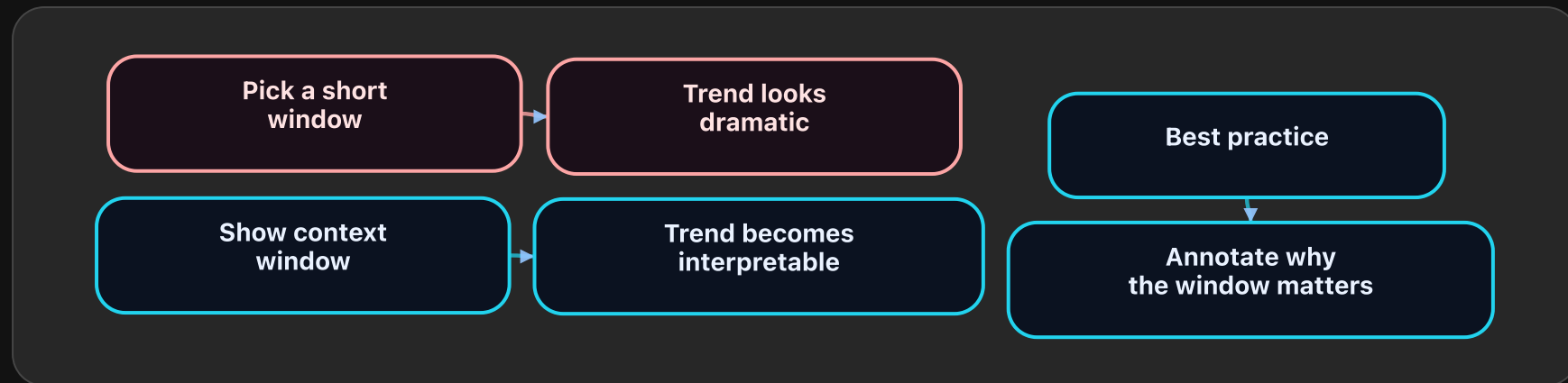
Pitfall: Choropleths of Counts (Map Misuse)

```
┌─────────────────┐     ┌─────────────────┐     ┌─────────────────┐
│   Choropleth    │ →   │   Coloring by   │ →   │  Large regions  │
│      map        │     │   raw counts    │     │    dominate     │
└─────────────────┘     └─────────────────┘     └─────────────────┘

┌─────────────────┐     ┌─────────────────┐     ┌─────────────────┐
│       Fix       │ →   │   Use rates /   │ →   │      Show       │
│                 │     │   per-capita    │     │   denominator   │
└─────────────────┘     └─────────────────┘     └─────────────────┘
```

Pitfall: Inconsistent Scales Across Panels

Small
multiples → If scales
differ → Comparisons become
invalid

Best
practice → Share axes
for comparison → If not,
label clearly
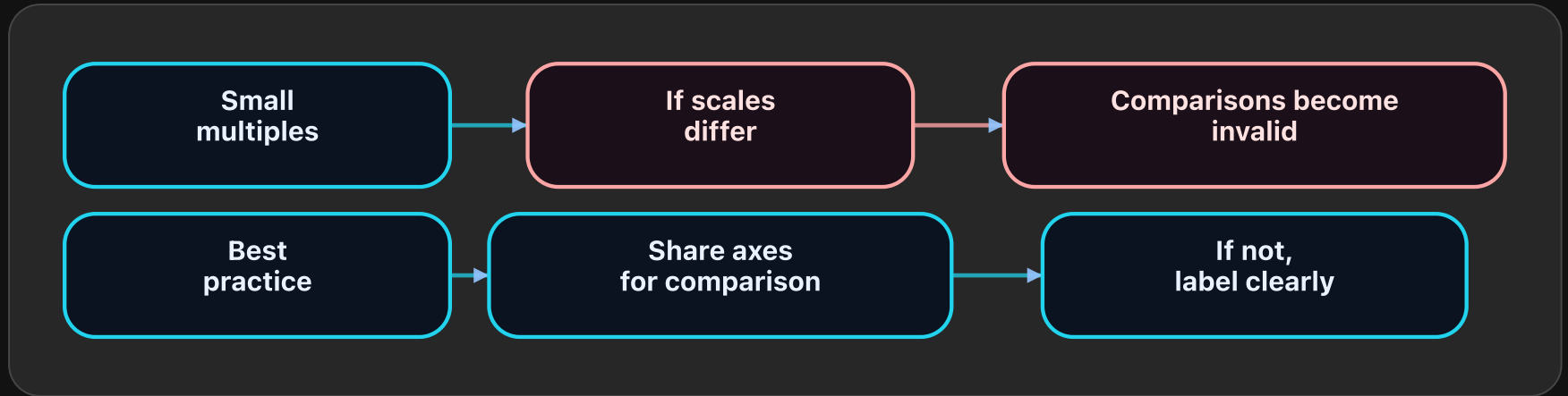
Pitfall: Category Order and Sorting

UNSORTED CATEGORIES

Hide ranking patterns

Readers waste time scanning.

SORTED CATEGORIES

Make comparisons effortless

Sort by value, by meaningful order, or by grouping.

Sort rule → Rank by value → Or use domain order → Or group + sort within group

Pitfall: Color Implies Meaning You Didn't Intend

COMMON FAILURE

Sequential color on categories implies order.

READER CHECK

Is the color scale labeled?

If not, don't assume magnitude.

DESIGNER FIX

Use qualitative hues for categories

Reserve sequential/diverging for ordered measures.

Audit, then redesign

Build trust by catching problems early.

A Fast Audit Checklist (Before You Trust a Chart)

CLAIM

What is this chart trying to prove?

Is the claim specific and verifiable?

DATA

What is included/excluded?

Any missing values, filtering, or transformations?

ENCODING

Are channels appropriate?

Position vs area; color type matches data type.

SCALE

Baselines + axes correct?

Truncation, log scales, inconsistent panels.

UNCERTAINTY

Could noise or sample size change the story?

Look for n, intervals, or distributions.

Critique Drill (In Groups)

Find 3 problems and propose 3 fixes.

- Identify the *claim* the chart is making (1 sentence).

- List 3 potential issues (axes, color, encoding, aggregation, missingness).

- Propose 3 fixes (chart type, scale, palette, labels, transforms).

- Decide whether the original claim still holds after your fixes.

"Spot the Pitfall" (Quick Check)

SCENARIO

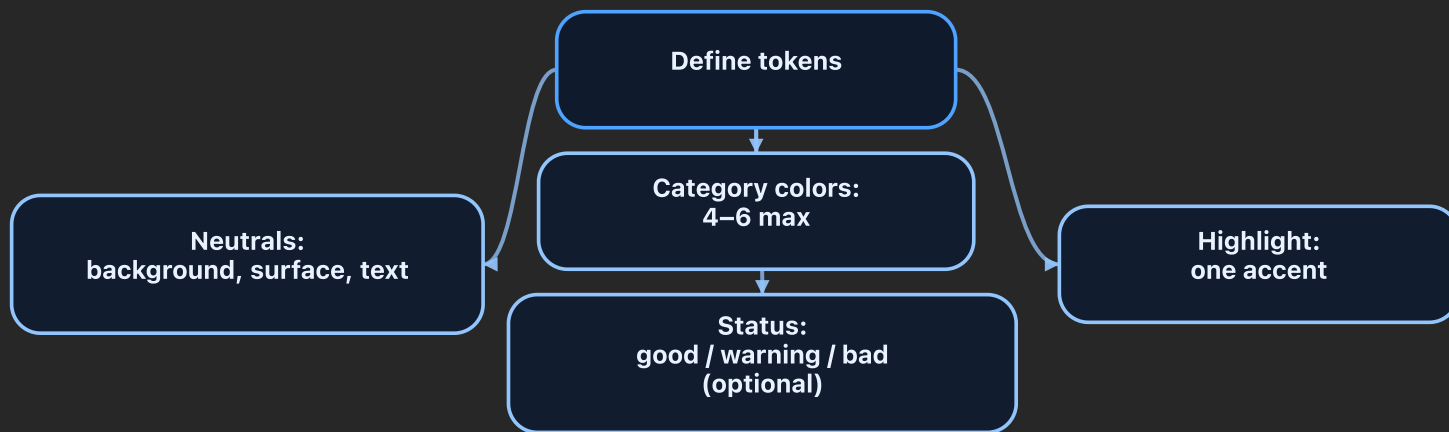**A bar chart shows a tiny change as a huge jump.**

What do you check first?

SCENARIO

A heatmap looks like it has "bands."

What do you check first?

- Bar chart: check the y-axis minimum and baseline.

- Heatmap: check the color scale type (sequential? labeled?) and whether it's uniform in lightness.

- Both: check if the claim matches the data + transformations.

Build a Simple Color System for Your Project

```
                    ┌─────────────────┐
                    │  Define tokens  │
                    └─────────────────┘
                             │
   ┌──────────────────┐      ▼      ┌──────────────────┐
   │    Neutrals:     │   ┌──────────────────┐   │    Highlight:    │
   │ background,      │   │ Category colors: │   │   one accent     │
   │ surface, text    │   │   4–6 max        │   └──────────────────┘
   └──────────────────┘   └──────────────────┘
                             │
                             ▼
                    ┌──────────────────┐
                    │    Status:       │
                    │ good / warning / bad │
                    │ (optional)       │
                    └──────────────────┘
```

OUTCOME

Your charts look cohesive because your colors are consistent.

Wrap-up + Practice

TAKEAWAYS

- Use position/length for accurate comparisons; avoid area for precision tasks.
- Use hue for categories, lightness for magnitude, diverging for baseline differences.
- Design accessibly: contrast + redundancy + labeled scales.
- Read charts with a checklist: claim → data → units → axes → encoding → aggregation → uncertainty.

Ethics: Be persuasive by being clear — not by manipulating perception.

WHAT TO PRACTICE

- Critique one real chart (write the claim + 3 issues + 3 fixes).
- Redesign one misleading choice (axis, encoding, palette, aggregation).
- Apply accessibility basics (contrast, direct labels, "no data" handling).
- Reuse a consistent palette system across your project.

References (Recommended)

Ware, C. (2012)

Information Visualization: Perception for Design (3rd ed.)

Publisher page

Cleveland, W. S., & McGill, R. (1984)

Graphical perception: Theory, experimentation, and application

https://doi.org/10.1080/01621459.1984.10478080

Munzner, T. (2014)

Visualization Analysis & Design

Author page

Okabe, M., & Ito, K. (2002)

Color Universal Design (palette guidance)

https://jfly.uni-koeln.de/color/