Data Visualization, 1e

Chapter 4: Purposeful Use of Color

Chapter Objectives (1 of 2)

After completing this chapter, you will be able to:

LO 4.1 Describe hue, saturation, and luminance and differentiate between them.

LO 4.2a Describe the differences between color psychology and color symbolism

LO 4.2b Explain how each color psychology and color symbolism can be used effectively

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Chapter Objectives (2 of 2)

LO 4.3   Design color schemes that are appropriate for categorical data, ordered data, and quantitative data with meaningful reference values

LO 4.4   Define colors in data visualization software using the hue, saturation, luminance (HSL) system

LO 4.5   Create data visualizations using colors that are easier for the audience to interpret

LO 4.6   List common mistakes made when using color in data visualizations and how to avoid them

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Data Visualization Makeover

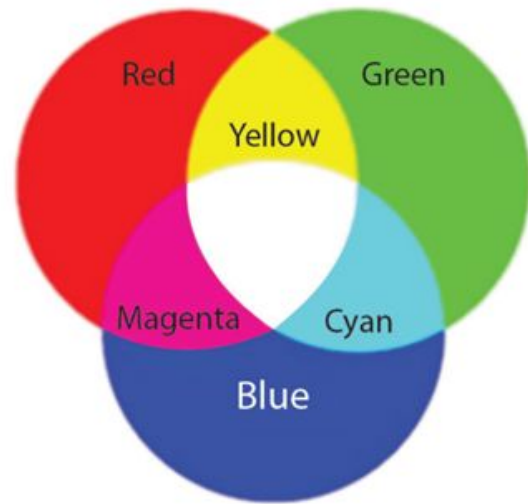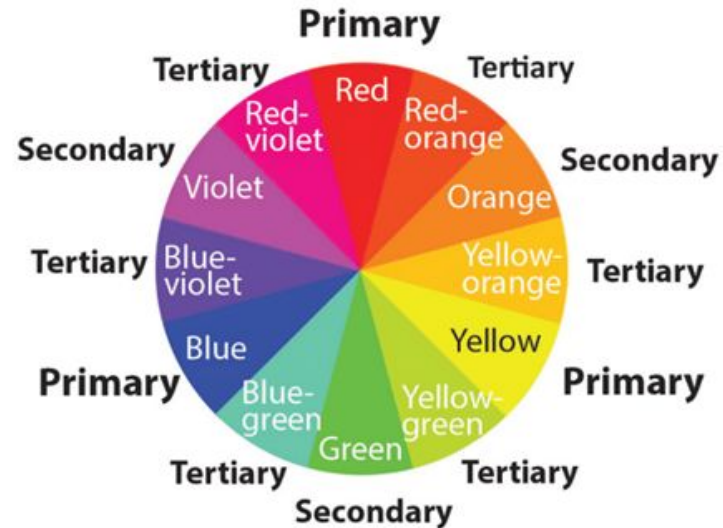## Versions of cover art for Ted Williams's The Science of Hitting

(a) Original Cover Art   (b) First Revision   (c) Second Revision

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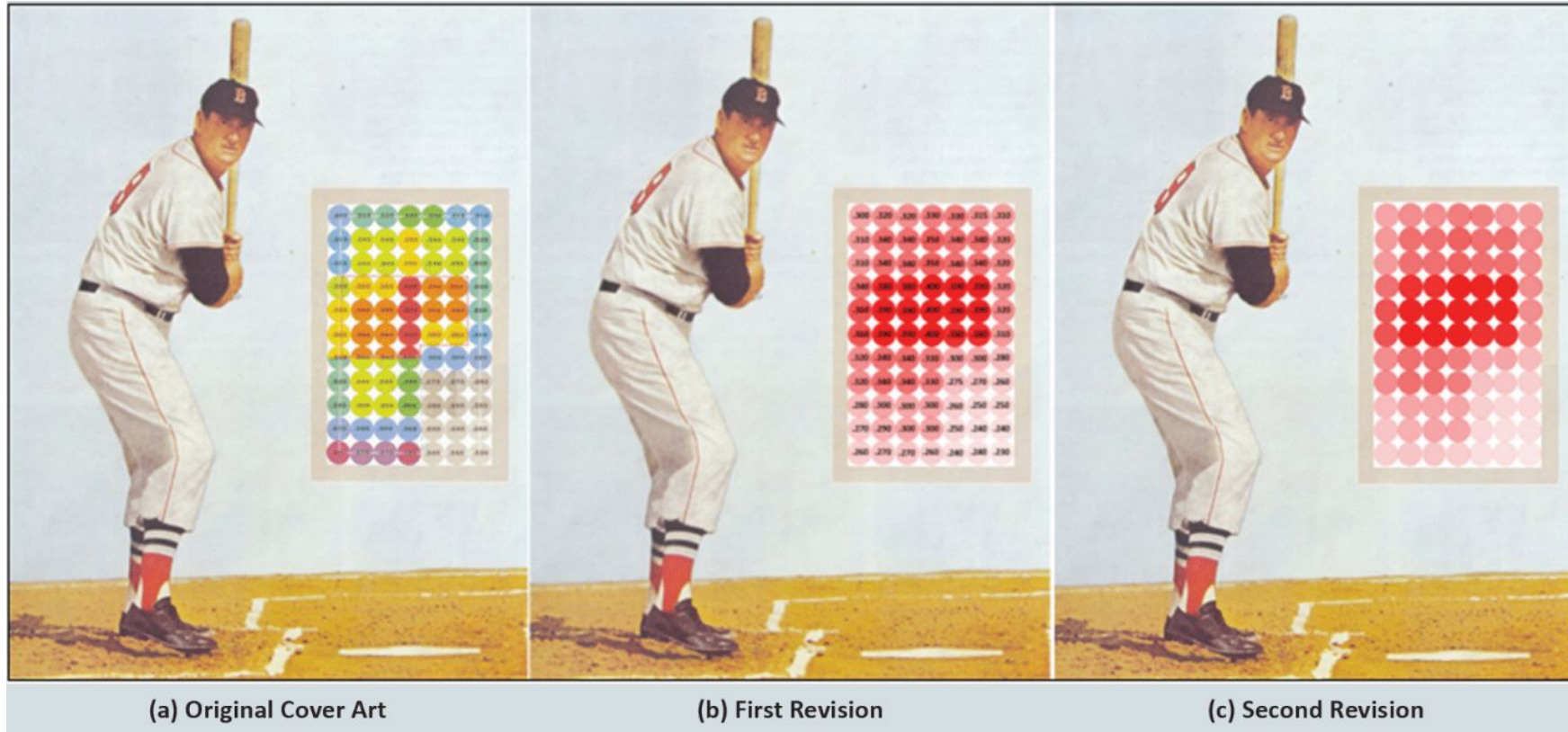
Color

Color is the property of an object that results from how the object reflects or emits light.

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4.1 Attributes of Color: Hue

## The RGB primary color model and color wheel

Color Model

Color Wheel

Hue is the base of color. The **primary hues** (red, green, and blue) form the **color model**. The primary hues cannot be mixed or formed by any combination of other hues.

Combinations of primary hues create secondary and tertiary colors, as displayed in the **color wheel**.

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4.1 Attributes of Color: Saturation

Primary hues in the RGB primary color model at different levels of saturation
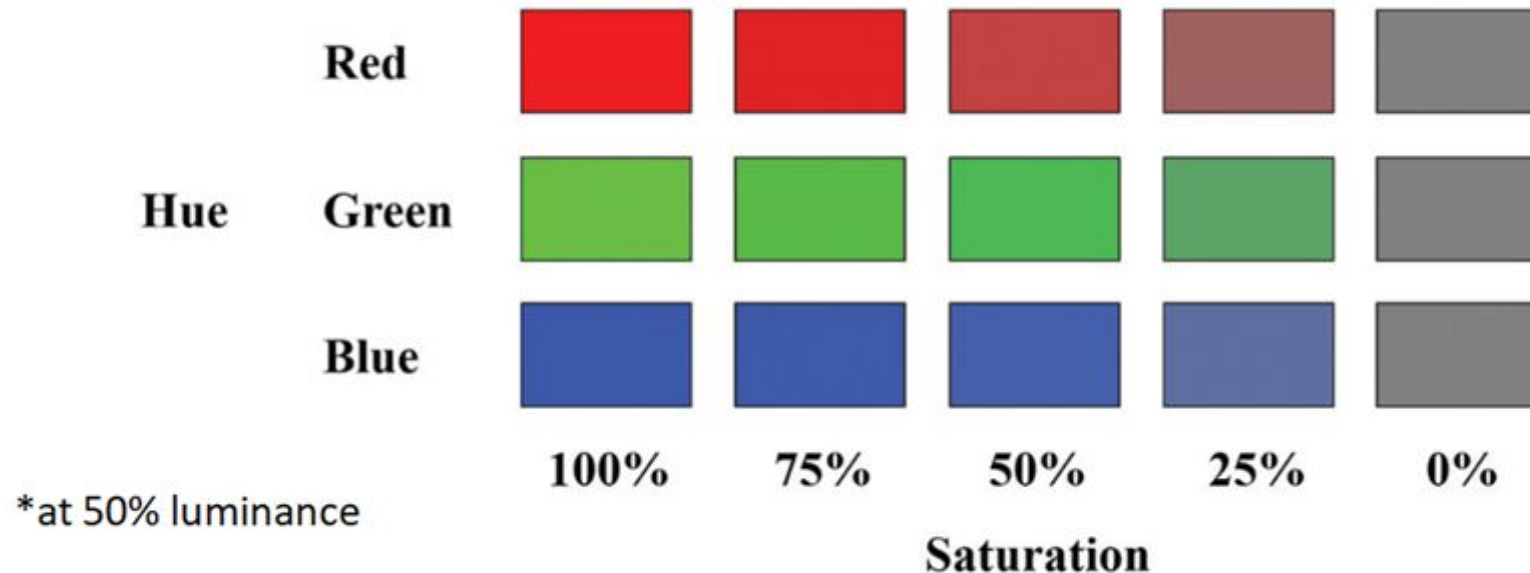
Saturation is the attribute of a color representing the amount of gray present. It determines the hue's intensity or purity. A pure hue has no grayness and is 100% saturated.

4.1 Attributes of Color: Luminance

Primary hues in the RGB primary color model at different levels of luminance
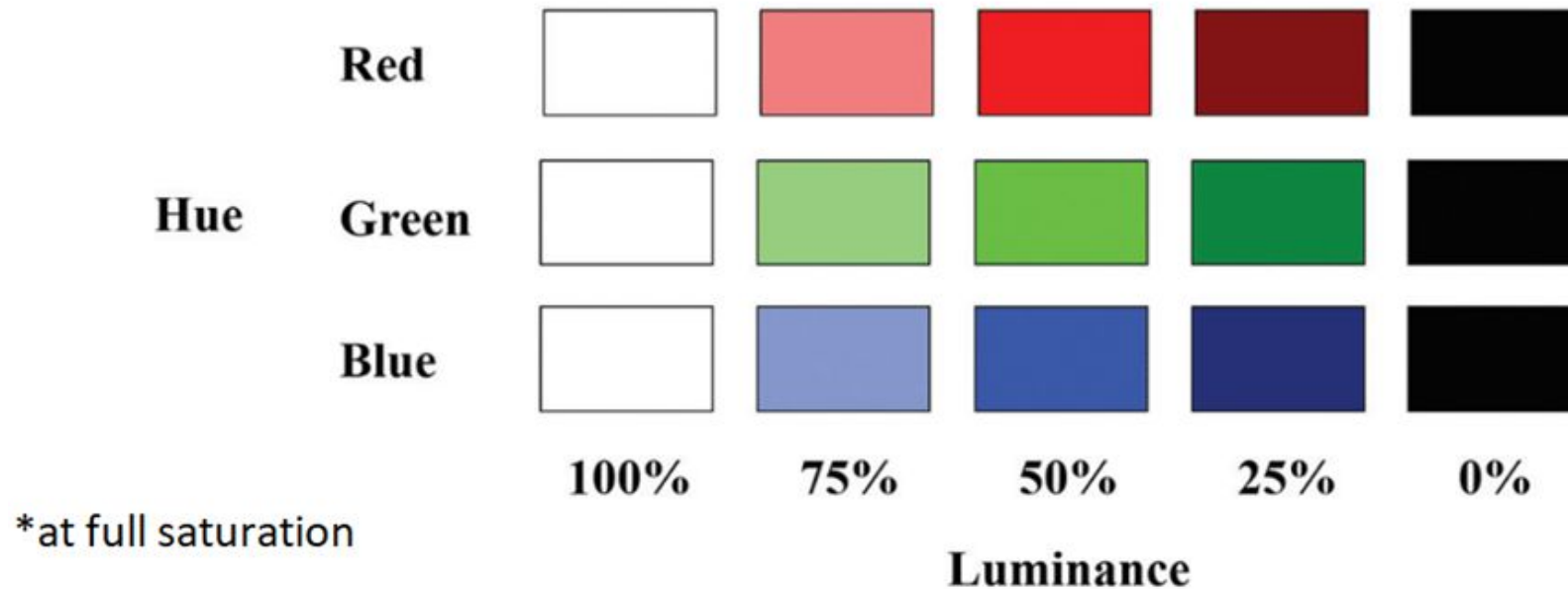
Luminance measures the relative degree of black or white within a color – the brightness of a color.

Adding white to a hue creates a brighter color and adding black to a hue creates a darker color.

4.1 Color Psychology and Color Symbolism

Color psychology: the study of the innate relationships between color and human behavior.

We perceive **Cool hues** (**purple**, **blue**, and **green**) as soothing, calming, and reassuring.

Warm hues (**yellow**, **orange**, and **red**) evoke energy, passion, and danger.

Color symbolism refers to the cultural meanings and significance associated with color.

Color symbolism differs much more across cultures than color psychology does and can change over time.

4.1 Perceived Color

Traits frequently associated with various colors

COLOR	MEANINGS AND ASSOCIATIONS	COLOR	MEANINGS AND ASSOCIATIONS
Red	Anxiety, Arousing, Daring, Dominant, Energy, Excitement, Health, Life, Love, Passion, Power, Protection, Spirited, Stimulating, Strength, Up-To-Date	Purple	Authenticity, Charming, Dignified, Exclusive, Luxury, Quality, Regal, Sensuality, Sophistication, Spiritual, Stately, Upper Class
Orange	Abundance, Arousing, Comfort, Daring, Excitement, Extraversion, Fun, Happiness, Lively, Security, Sensuality, Spirited, Warmth	Pink	Charming, Cheerful, Feminine, Gentle, Nurturing, Sincerity, Soft, Sophistication, Tranquility, Warmth
Yellow	Arousing, Cheerful, Confidence, Creativity, Excitement, Extraversion, Friendliness, Happiness, Optimism, Self-Esteem, Sincerity, Smiley, Spirited	Brown	Nature, Outdoorsy, Reliability, Ruggedness, Security, Support, Tough
Green	Calm, Comfort, Equilibrium, Harmony, Health, Hope, Nature, Outdoorsy, Peace, Prosperity, Relaxation, Security, Serenity, Soothing, Tender	Black	Dignified, Efficiency, Elegance, Emotional Safety, Glamour, Power, Richness, Ruggedness, Security, Sophistication, Stately, Substance, Tough, Upper Class
Blue	Calm, Comfort, Competence, Coolness, Dignified Duty, Efficiency, Intelligence, Logic, Peace, Reflection, Relaxation, Reliability, Security, Serenity, Soothing, Successful, Tender, Tranquility, Trust	White	Calm, Clarity, Cleanness, Down-to-Earth, Happiness, Heavens, Honest, Hygience, Innocence, Peace, Purity, Serenity, Sincerity, Soothing, Tender

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4.1 Perceived Color and Background

Perceived color changes as contrast with the background color changes

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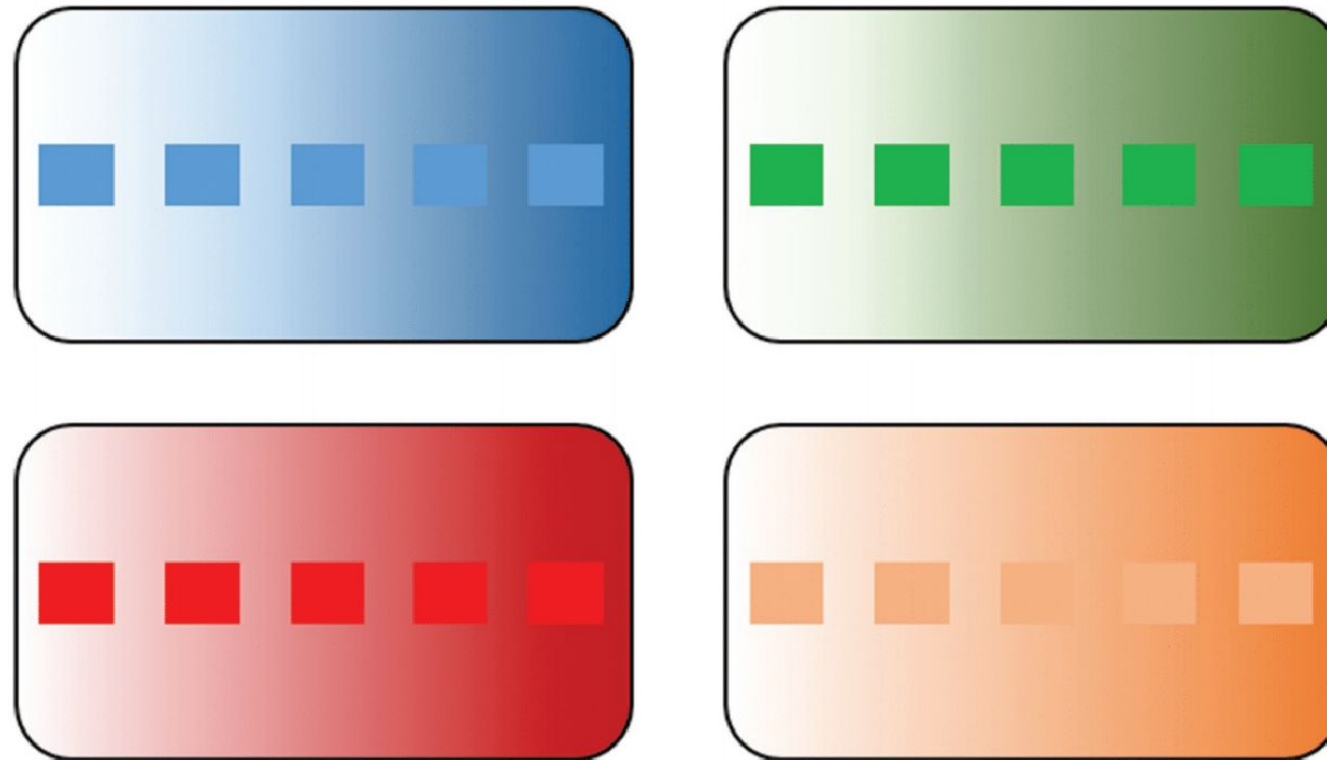
4.1 Complementary and Analogous Colors

Complementary colors are directly opposite each other on the color wheel.

- Create dissonance

- Useful to make objects in a display stand out

Analogous colors are directly adjacent to each other on a color wheel.

- Appear softer and smoother than complementary colors when used together

Overuse of complementary and analogous colors increases **cognitive load** and may distract the audience.

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4.1 Suggestions for the Use of Color in Data Visualization

- Poor and unnecessary use of color creates clutter and increases the audience's cognitive load.

- A multicolored background for data visualization can be distracting.

- Cool colors appear more distant than warm colors.

- Complementary colors used together create color dissonance.

- Analogous colors create more color harmony than complementary colors.

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4.2 Color Scheme

The **color scheme** is the set of colors (hues, saturations, and luminances) in data visualization.

The color scheme depends on the type of data used in the data visualization and the message we want to convey to the audience.

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4.2 Categorical Color Schemes

Colorful

In a **categorical color scheme**, distinct and unordered color groups represent a categorical variable's outcomes.

To set the **Colorful** palette shown to the left:
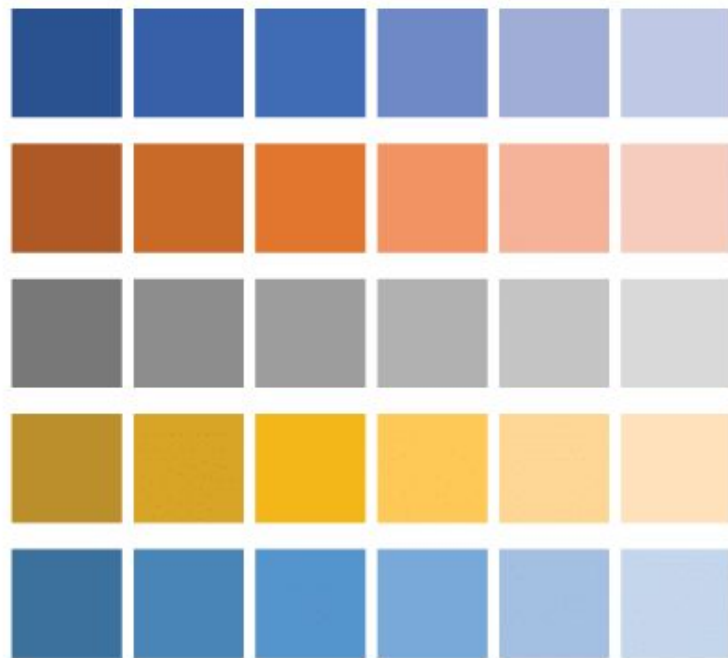
Step 1. Click anywhere on the chart

Step 2. Click on the **Page Layout t**ab on the ribbon

Step 3. Click on the **Colors** dropdown menu in the **Themes** group

Step 4. Select the **Office** theme

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4.2 Sequential Color Schemes

Monochromatic

In a **sequential color scheme**, the gradient of saturation or luminance of a hue represents the outcomes of an ordered variable.

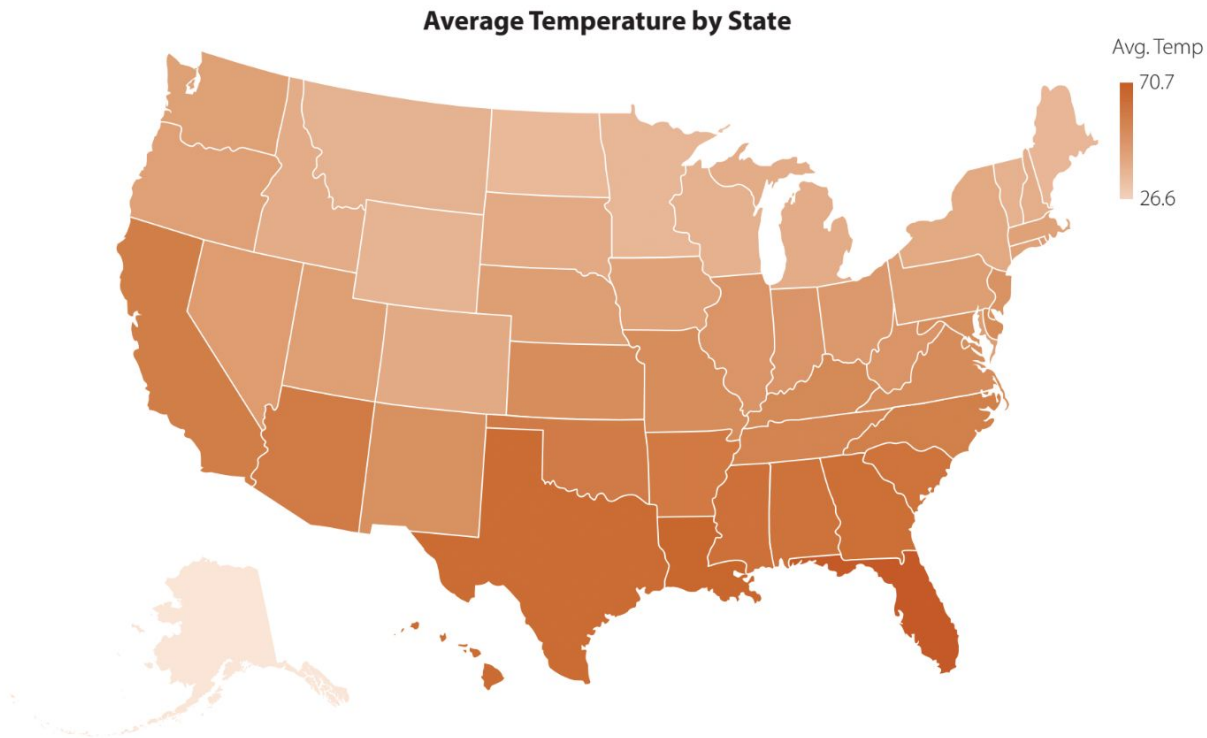To set a **Monochromatic** palette:

Step 1. Click anywhere on the chart

Step 2. Click on the **Chart Design** tab in the ribbon

Step 3. Click the **Change Colors** dropdown menu in the **Chart Styles** group

Step 4. Select one of the **Monochromatic** themes

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4.2 Sequential Color Schemes for Maps

Choropleth map of average annual temperature by state using brown

A monochromatic brown is more suitable to convey an idea of warmth to the audience.

4.2 Diverging Color Schemes

Heat map of monthly mean daily low temperature for Indianapolis 2010–2019

Monthly Mean Daily Low Temperature for Indianapolis

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010												
2011												
2012												
2013												
2014												
2015												
2016												
2017												
2018												
2019												

In a **diverging color scheme**, a gradient formed by two sequential color schemes sharing a common endpoint represents a quantitative variable.

Each sequential color scheme, one for values above the reference value and the other one below, uses a different hue with a gradient of increasing luminance as the values approach the reference value.

*See the notes for step-by-step instructions on how to build a heat map with a diverging color scheme.

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4.3 The HSL Color System

We can control the hue, saturation, and luminance (**HSL**) in Excel through the Colors dialog box as 0 to 255 integers.

Hue: the primary and secondary colors of the RGB primary color mode using fixed values for 100% saturation (Sat: 255) and 50% luminance (Lum: 128) are:

Color	Hue
Red	0
Yellow	40
Green	80
Cyan	120
Blue	160
Magenta	200

Sat: a higher saturation represents a purer color. A Sat value of 0 results in a gray tone.

Lum: a luminance of 255 results in the color white. A Lum value of 0 produces the color black.

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4.3 Setting the Hue Parameter in the Colors Dialog Box
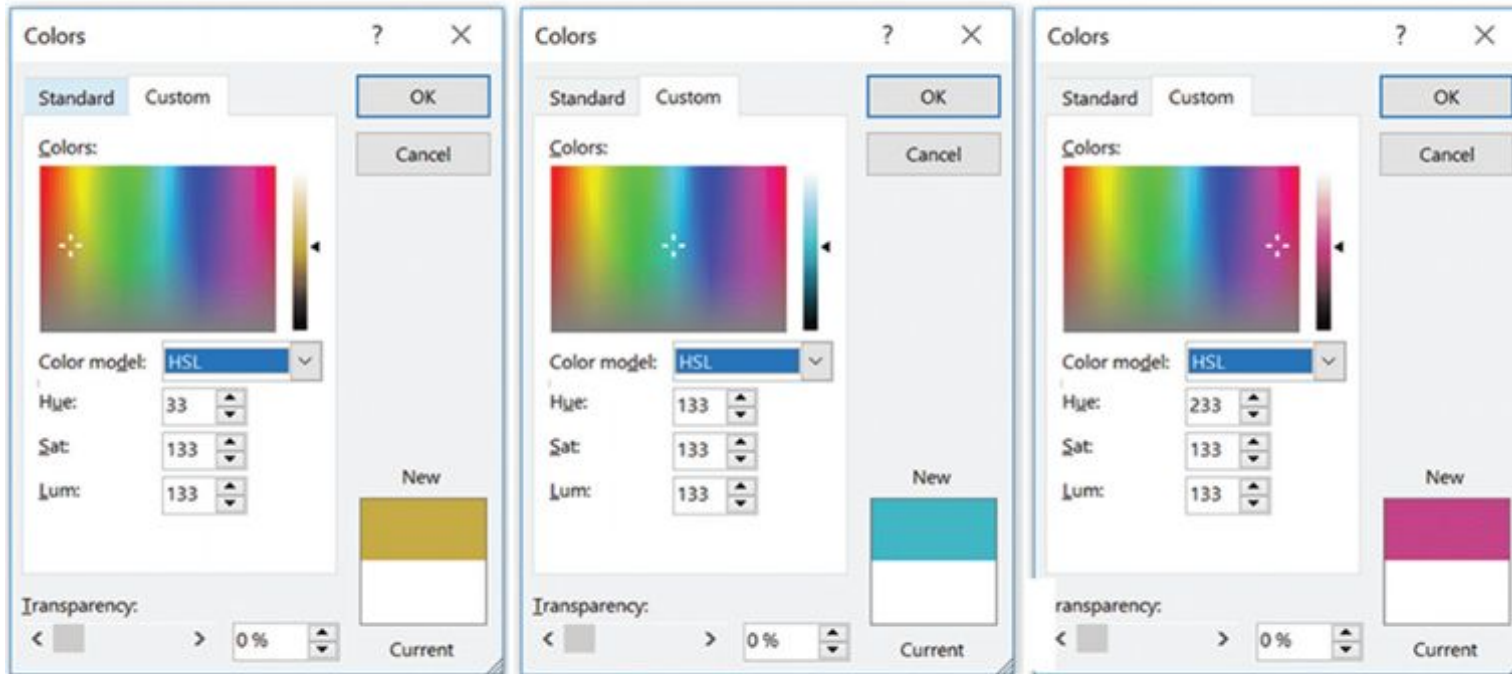
As the value of the **Hue** parameter increases, the crosshair indicator moves horizontally from left to right across the color spectrum control in the Colors dialog box to indicate the selected hue.

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4.3 Setting the Sat Parameter in the Colors Dialog Box
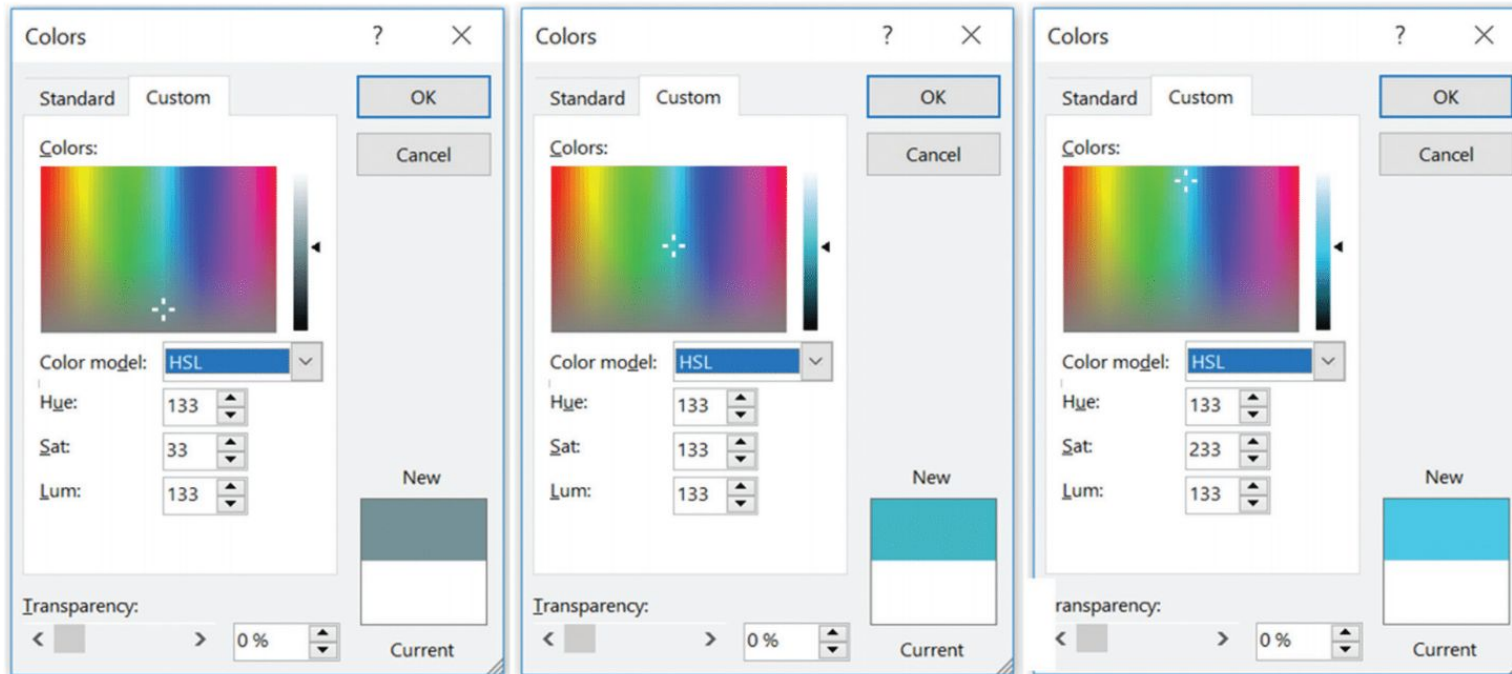
As the value of the **Sat** parameter increases, the crosshair indicator moves vertically from bottom to top across the color spectrum control in the Colors dialog box to indicate the selected saturation, which alters the grayness/increases the purity of the color.

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4.3 Setting the Lum Parameter in the Colors Dialog Box
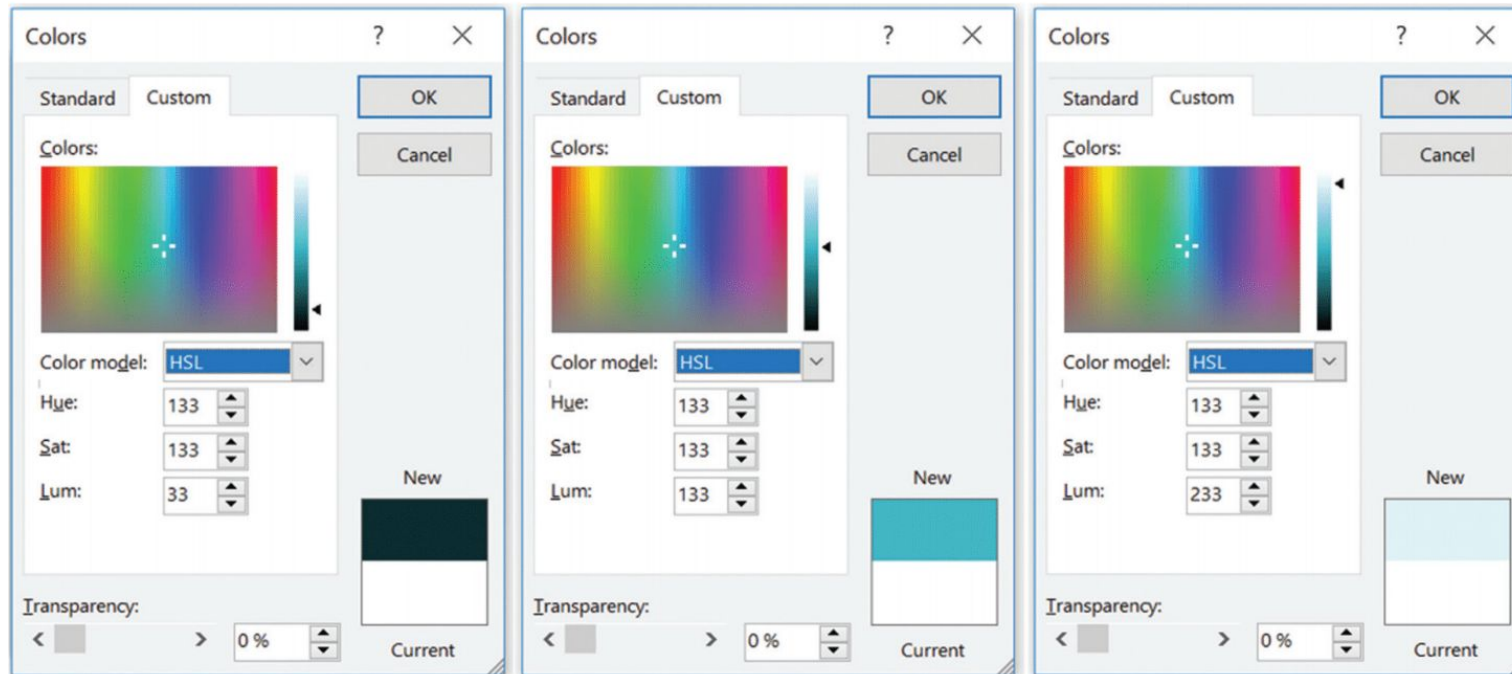
As the value of the **Lum** parameter increases, the ◄ indicator moves vertically from the bottom to the top of the Luminosity slide control in the Colors dialog box to indicate the selected luminance, which reduces and increases the lightness of the color.

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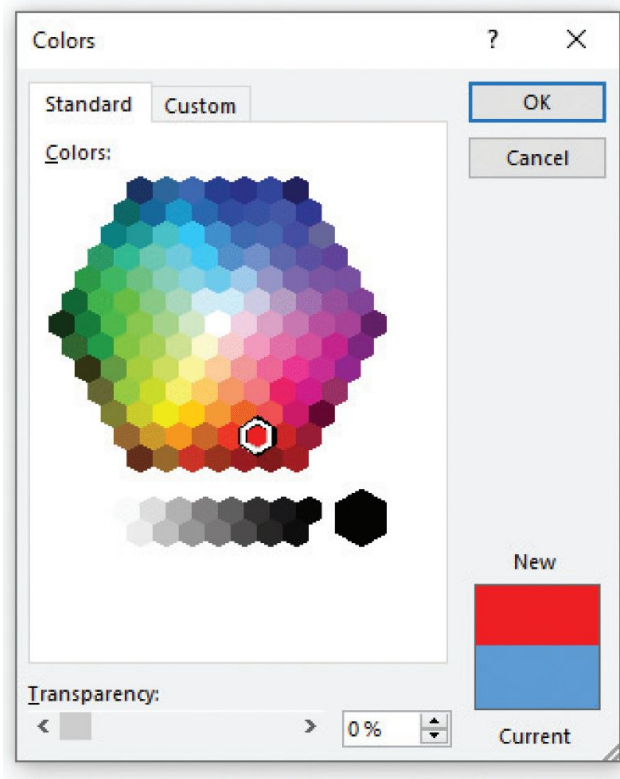# 4.3 Replicate a Color Using the Eyedropper Tool

Grappenhall Publishers logo

Hue, Sat, and Lum settings used in the Grappenhall Publishers logo
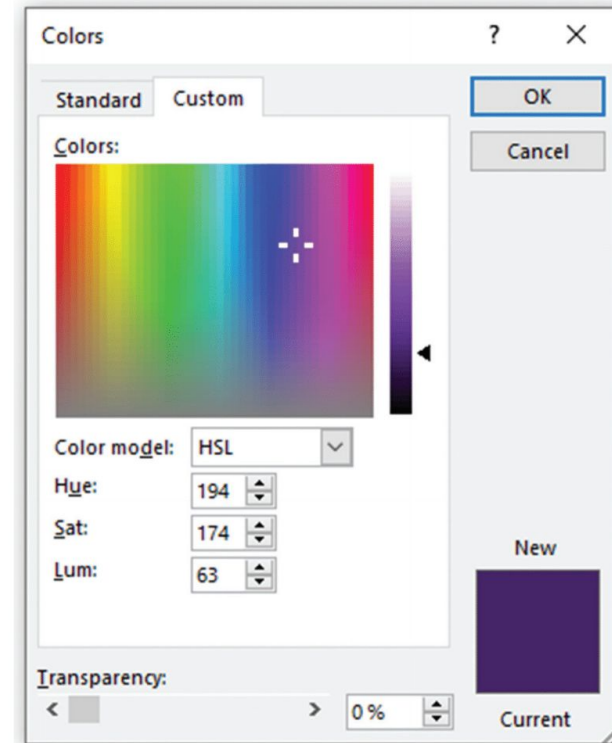
*See the notes for step-by-step instructions on how to replicate a color using the eyedropper tool.
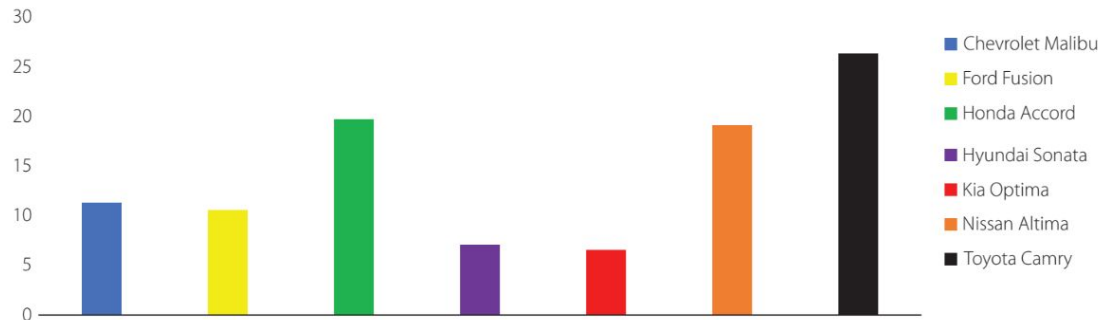
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4.3 Custom Color Using the RGB Color System

Step 1. Access the RGB Color System by selecting **RGB** from the **Color model:** dropdown menu in the **Colors** dialog box. Then, select the **Standard** tab in the **Colors** dialog box.

Step 2. Click on a particular hexagon to invoke the desired color. The new color will appear on the **New-Current** box in the lower right of the dialog box.
Click **OK** to change the object to the new color.

The **Transparency** slider controls how much you see-through in a color.

Step 3. Drag the **Transparency** slider or enter a number between 0 and 100 to vary the percentage of transparency from 0 (fully opaque, the default setting) to 100% (fully transparent).

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4.4 Unnecessary Color

Use of hue and a legend to identify categories

US Unit Sales for Top Selling Midsize Sedans

Sales (1000s)

- Chevrolet Malibu
- Ford Fusion
- Honda Accord
- Hyundai Sonata
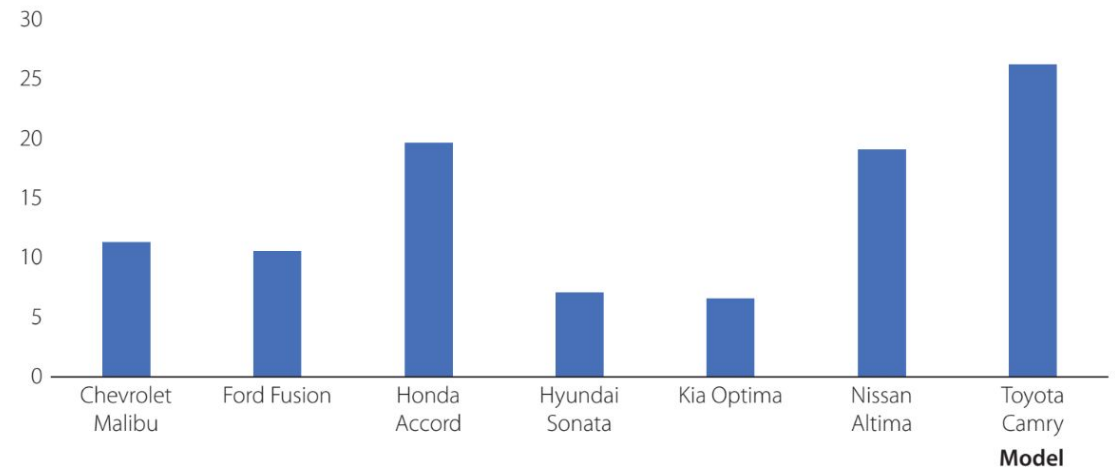- Kia Optima
- Nissan Altima
- Toyota Camry

Use of horizontal axis labels to identify categories

US Unit Sales for Top Selling Midsize Sedans

Sales (1000s)

Model

- The horizontal axis label replaces the legend with category names.

- A single color replaces the colorful palette.

- The audience can now follow the chart from left to right with a reduced cognitive load.

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4.4 Excessive Color

Line chart of the quarterly house price index by state with too many colors

Quarterly House Price Index by State (Base = 1991)
Home Price Index

Legend: AK, AL, AR, AZ, CA, CO, CT, DC, DE, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV, WY

(data from https://www.fhfa.gov/DataTools/Downloads/Pages/House-Price-Index-Datasets.aspx)
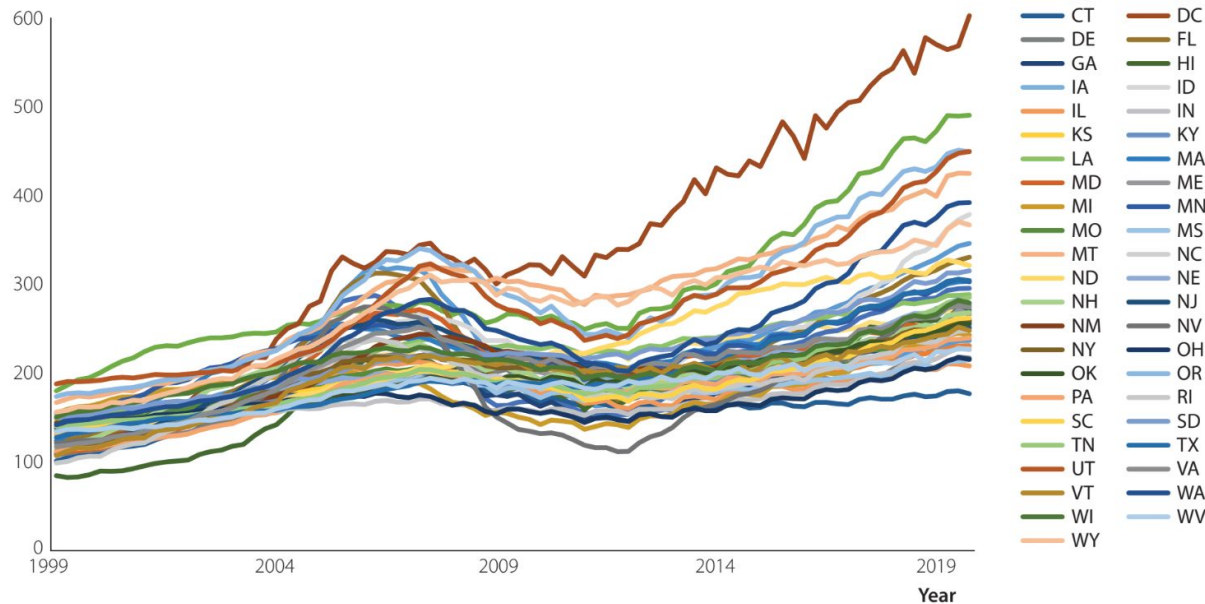
The chart shows quarterly house-price indexes from 1992–2019 for each state and the District of Colombia.

The chart objective emphasizes the westernmost states in the continental United States (Arizona, California, Nevada, Oregon, and Washington.)

With 51 categories/colors on this chart, comparing housing prices across states is difficult.

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4.4 Reducing Excessive Color

Chart of quarterly house price index by state with more efficient use of color

Quarterly House Price Index (Base = 1991) for Western States Demonstrates More Volatility
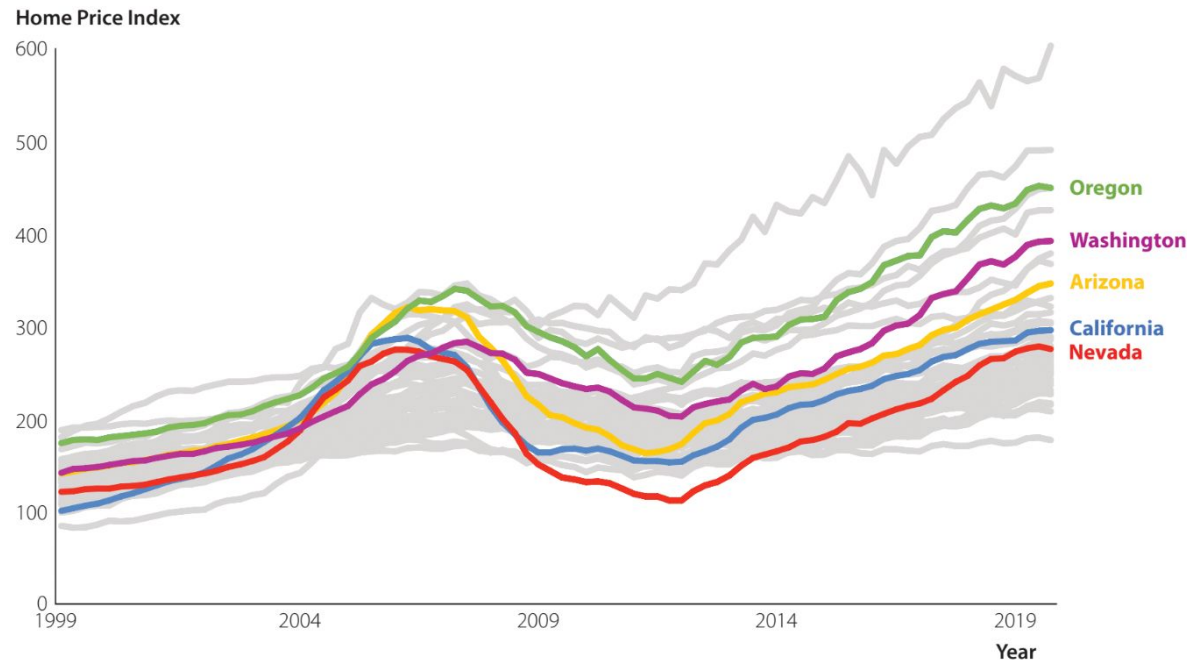
We can make it easier for the audience to find the westernmost states in the continental United States by:

- Applying a different color for each of these states and using gray for all other states.

- Removing the legend and adding a label for each of the five westernmost states in the continental United States to the end of their respective lines.
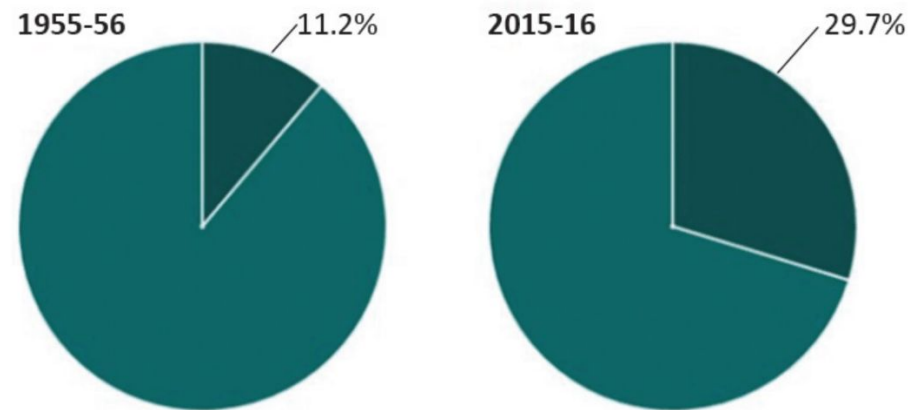
*See step-by-step instructions on how to produce the chart to the left in the notes.

4.4 Insufficient Contrast

Lack of contrast makes it more challenging to differentiate between the pie chart slices

Increased contrast makes it easier to differentiate between the pie chart slices
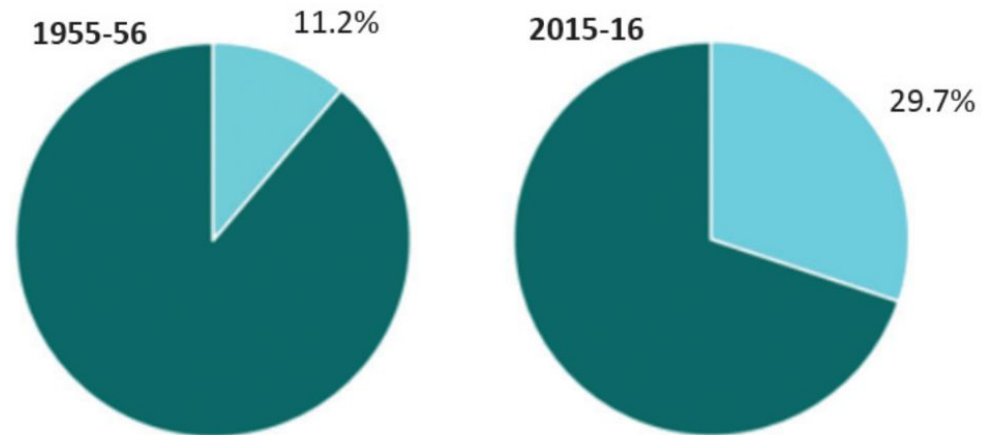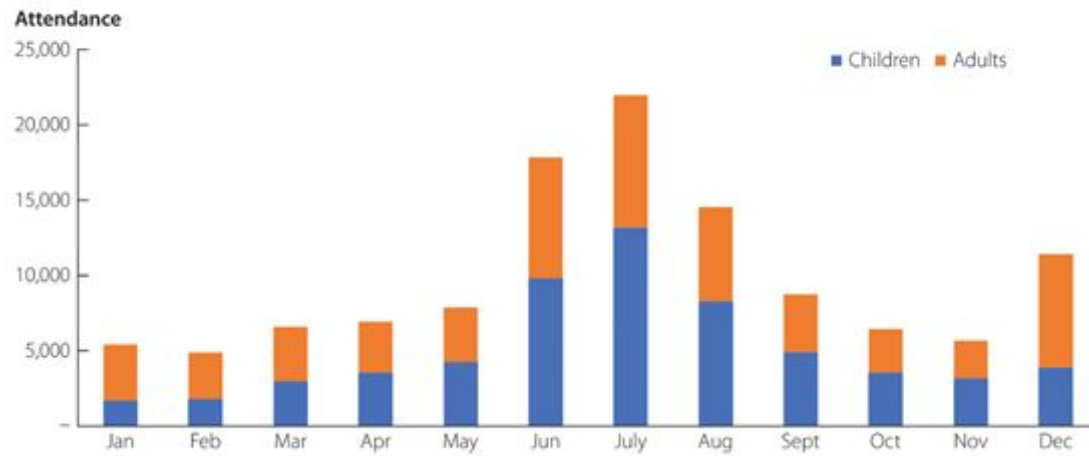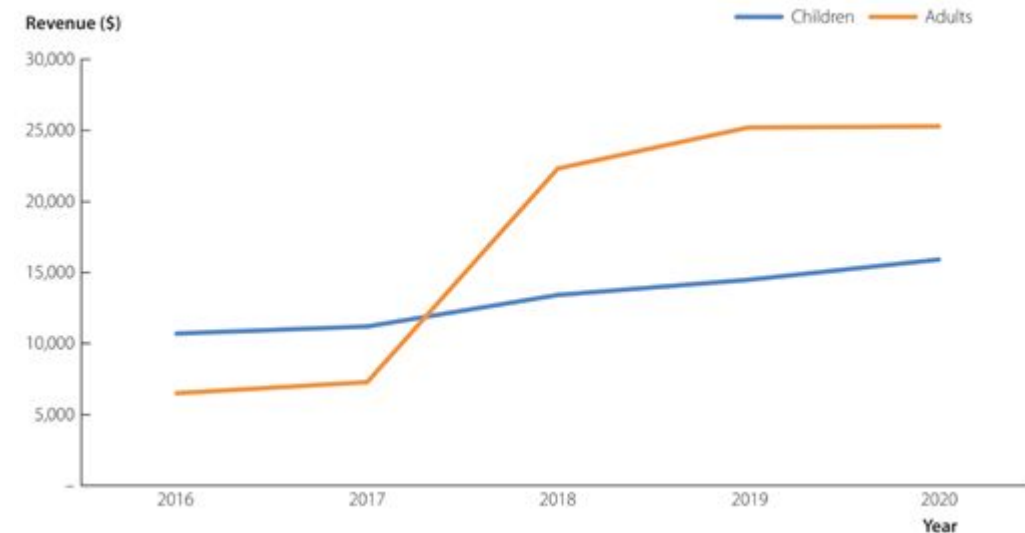

The increase in luminance difference increases the contrast between the two slices of each pie chart, making it easier for the audience to focus on the NHS portion of the budget.

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4.4 Inconsistency Across Charts

A stacked column chart of children and adult zoo attendance for the last year

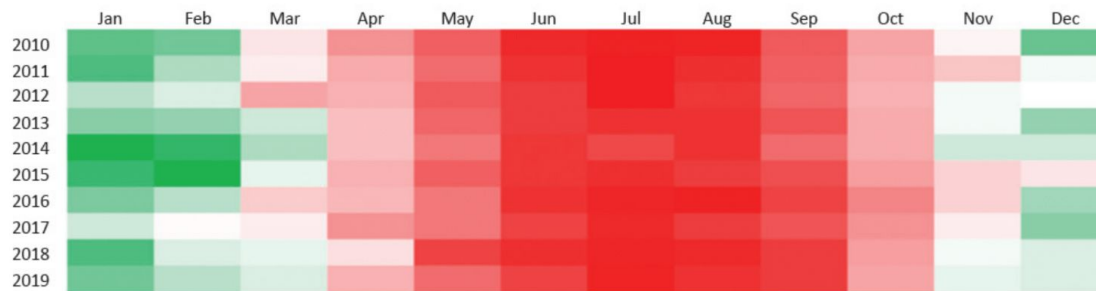**A line chart of ticket revenue for December across several years**

The consistent use of colors, orange and blue for adults and children, helps the audience comprehend the data presented across a series of related slides.

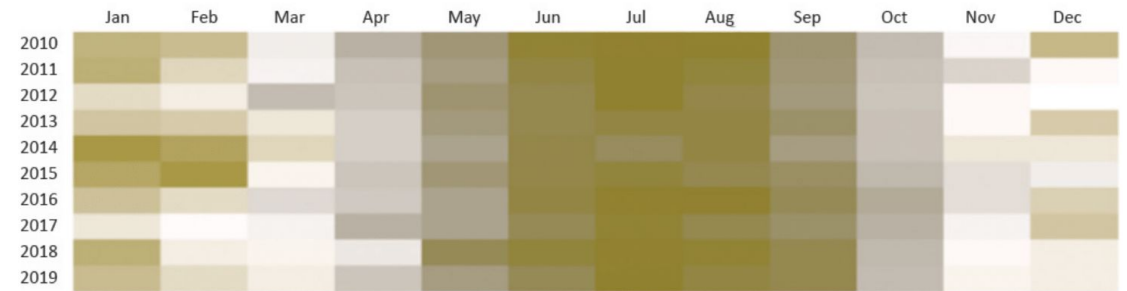CENGAGE

4.4 Neglecting Colorblindness

Heat map of monthly mean daily low temperature for Indianapolis 2010–2011

Heat map as It may appear to someone who is red-green colorblind

Colorblindness, or a reduced ability to accurately perceive some colors, occurs when at least one of the three types of cones in a retina is insensitive to the wavelength of light responsible for sensing.

The most common form of colorblindness is red-green colorblindness.

*See additional comments in the notes.

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4.4 Neglecting Mode of Delivery

- Color works differently in print and projection.

- Projected presentations should:
  - Use thick lines, sharp outlines, color contrast, and relatively high saturation and luminance.
  - Colors vary across projectors. When possible, review the entire presentation in advance with the projection equipment to give the actual presentation.

- Printed presentations should:
  - Use softer outlines with less saturated colors, lower luminance, and less contrast.
  - Colors vary across printers. Consider printing a test page that includes each of the colors used in the report on the same printer you will use to print the report.

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Discussion Activity

- Consider the choropleth maps of average annual temperature by state shown in slide 17. We learned how to indicate the gradient of a quantitative variable, such as temperature, using different levels of luminance for the same hue, and how we can play on the psychology of color to convey coolness (blue) vs. warmth (brown) in the audience.
  - Suppose you need to create a choropleth map of median family income by state (data not available.) What color scheme would you choose to convey the message to the audience and why? Define the color scheme, hue, and luminance selected for this case..
  - What if you instead need to create a choropleth map of changes in median family income by state (data not available) over the past decade (such as 2010 vs. 2020.) What color scheme would you choose to convey the message to the audience and why? Define color scheme, hues, and luminance selected for this case.

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Check Your Knowledge

1.   When the groups of the categorical variable have no inherent ascending or descending order, the variable is well suited for representation by _____.

   a.   a sequential color scheme for each of its unique groups
   b.   a distinct color for each of its unique groups
   c.   analogous colors for each of its unique groups
   d.   warm hues for each of its unique groups

2.   Which of these is not a common color usage mistake in data visualization?

   a.   Inconsistency across related charts
   b.   Not considering the mode of delivery
   c.   Insufficient contrast
   d.   Reusing the same color scheme for multiple charts

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Summary

In this chapter, you should have learned how:

- To use color to define the pre-attentive attributes of hue, saturation, and luminance.

- To distinguish between color psychology and color symbolism and use them effectively in data visualizations.

- To design color schemes that are appropriate for the different variable types with a meaningful reference value.

- To use the HSL system for defining color in Excel.

- The common mistakes made when using color, including neglecting to consider colorblindness, may affect the outcome of data visualizations.

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