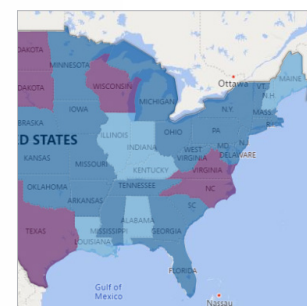
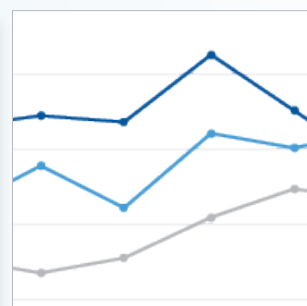
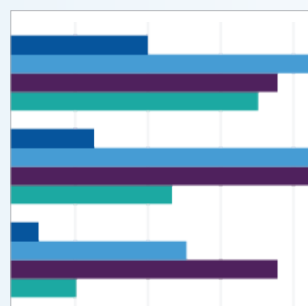
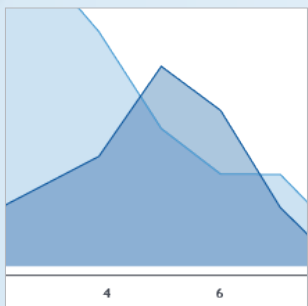
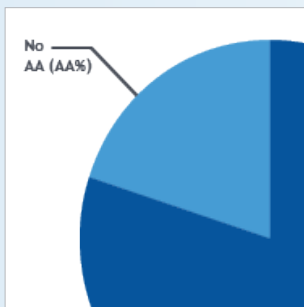
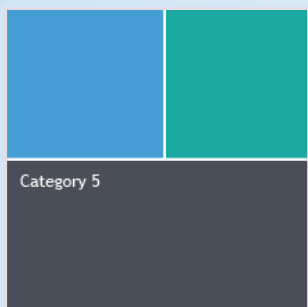
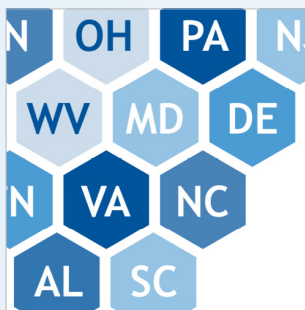
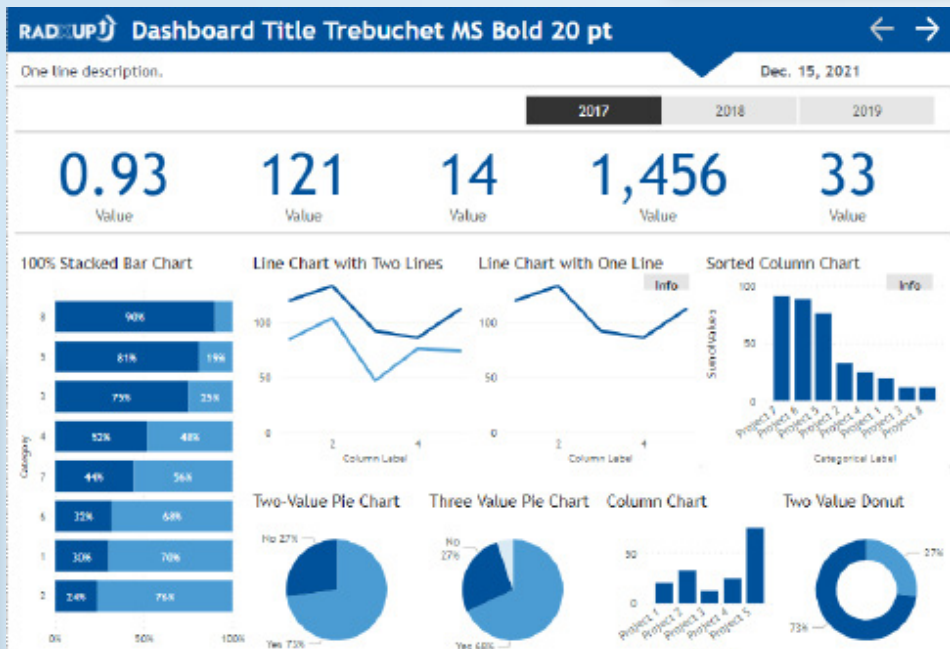
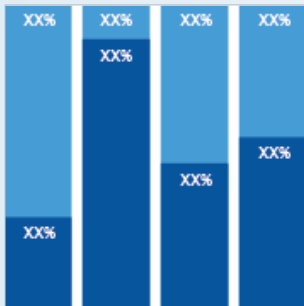


Data Visualization Style Guide



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Introduction

The National Institutes of Health (NIH) launched the Rapid Acceleration of Diagnostics (RADx®) initiative to speed innovation in the development, commercialization, and implementation of technologies for COVID-19 testing. Accurate, fast, easy-to-use, and widely accessible testing is required before the nation can safely return to normal life. RADx® Underserved Populations (RADx-UP) was created by the NIH to ensure that all Americans have access to COVID-19 testing, with a focus on communities most affected by the pandemic.

The American Institutes for Research developed this RADx-UP Data Visualization Guide, as part of the Coordination and Data Collection Center (CDCC) consortium. The CDCC serves as the central leadership and support team assisting the NIH and more than 125 RADx-UP grantees across the United States and its territories as well as Tribal Nations.

The goals of RADx-UP projects are to: (1) establish community-engaged research studies across the country to evaluate a variety of testing methods in specific populations, areas, and settings, and (2) strengthen collaboration between RADx-UP projects and their community partners to identify and address the unique needs of individuals in tribal health centers, houses of worship, homeless shelters, prison systems, and other settings.

The goal of this guide is to support the CDCC, grantees, and project staff with performance monitoring and to help develop materials and reports that are accessible to a variety of audiences.

Grantees and other data users can use this guide to:

- Learn about key best practices to consider when presenting data;
- Select chart types that are most appropriate given the available data;
- Identify when and how to group data into more complex presentations in reports, posters, dashboards, or infographics;
- Learn about common formatting standards to improve readability of your charts and standardization across and within your deliverables based on the CDCC style guide,
- Learn how to develop charts and presentations to help meet 508 compliance requirements for individuals with disabilities;
- Review additional resources for further reading and trainings on the topic of data visualization.

You can share this document with your staff freely, and the current version will be maintained on the Resources page of the [RADx website \(www.radx-up.org\)](http://www.radx-up.org).

1. Choosing the Right Visualization for Your Data and Audience

Before developing graphic representations of your data, it is vital to start by determining the purpose, the audience, and the dissemination format (e.g., a report for policy makers that shows trends in testing). Each type of data visualization has strengths and weaknesses in conveying different types of information and data relationships. When initially thinking about how to display your data most effectively, ask yourself a few key questions:

- What insights do I want my audience to come away with? What is the story I want to tell? What action do I want them to take?
- What metrics and measures do I want to highlight? Do I have the data and information I need?
- What is the key data summary, including data subsets, trends, and relationships that will help the audience gain insight?
- Will the data be primarily reviewed in a static report or interactive dashboard medium that is updated periodically? How will this affect the visual forms I use to tell my story and the organization of information?

Based on these key factors, you can then conceptualize an overall design layout, selecting a set of appropriate visualizations for your data and use case scenarios. The following practices consider these questions in more detail.

Practice 1: Develop visuals for your audience, scaling complexity to fit your user’s experience.

Think critically about two key questions:

- (1) What is the key takeaway for your audience?
- (2) What is their general level of familiarity with the topic, the data, and data visualizations?

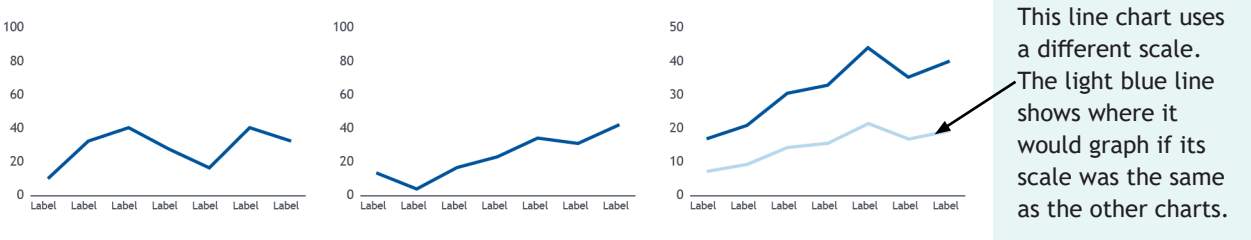
The first question should guide your chart selection, as well as your choice of visuals and data points to communicate the takeaways. The second question should also play a role in chart selection. For audiences with little data visualization experience, simpler bar charts, histograms, line charts, and maps are easier to interpret and may be less intimidating to the user. For example, audiences with little statistical experience may not be able to interpret p-values or correlation coefficients, so these elements may not need to be included in your chart. If your audience is familiar with more complex visualizations, you can explore a wider range of charts.

Practice 2: Avoid confusing or misleading data visualizations.

Sometimes, visualizations can confuse or mislead the audience if you display too much data or distort the presentation of data. Instead of overloading a single chart, focus on a specific data point or important trends. If trends in an entire dataset are the opposite of trends in a subset of the data, consider using a series of data visualizations, where you show both a big picture and a narrowly focused representation of data.

Also, avoid data misinterpretation by placing charts with the same scale next to each other and formatting your axes consistently. If you present multiple charts that are meant to be compared against one another, make sure the chart axes start and end at the same points.

Start axes for continuous measures at zero for all visuals except line charts, scatter plots, and



bubble charts. Line charts often include positive and negative values—for these visuals chose a meaningful range that includes the zero line. Depending on the nature of your data and the contextual knowledge of your audience, you may break the zero-baseline rule for line charts, and just choose a start number for the axis that structures the chart to show important changes in the data. For scatter plots and bubble charts, choose axis start and end points appropriately to emphasize the correlation that is displayed. Axis intervals should always be equally spaced.

Practice 3: Compile groups of visualizations intentionally.

Sometimes a set of visualizations are used to monitor various facets of an ongoing situation or track trends in the data. Often the purpose of a collection of visualizations is to tell a story about the data with and between them or allow the user to explore potential relationships in the data. If a more complex and integrated collection of visualizations is required to tell a story about a set of data points, variation with data across subgroups, and explore relationships or associations between various data points.

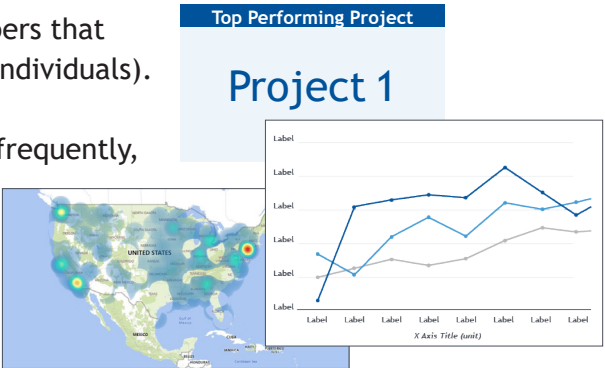
Dashboards are often used to present data that are updated regularly to track trends and the status of a datapoint. Infographics are often used to add context, interpretation, and highlights around the graphical presentation of the data, with the goal of walking the user through a topic and pulling out the key findings or takeaways that might not be obvious to a passive observer of charts and tables. The choice of whether to develop a dashboard or infographic should be clear once you have identified your audience’s needs. Detailed guidance on how to choose the right visualizations for your infographic or dashboard are found later in this document.

Here are a few visualizations that tend to be well suited to dashboards:

Card visuals to show the most recent values of numbers that receive frequent updates, (e.g., number of infected individuals).

Line charts to track trends in data that are updated frequently, (e.g., number of tests dispensed across a program over time and by site).

Maps to show the geographic implications of data, (e.g., distribution of projects across states).



Practice 4: Design the visual aspects of your final product holistically.

After you have identified the key messages you wish to convey or trends you wish to track, and the appropriate charts to visualize your data, take some time to consider how your visualizations should look, feel, and work together. If presenting multiple charts, use a consistent scale and orientation across your charts. Formatting, fonts, and colors are discussed in detail in Chapters 4 and 5.

Practice 5. Be transparent about the data used for the visualization.

Transparency in the data creates trust and avoids misinterpretation. Visualizations should include information about the data and assumptions about the data that help the audience contextualize and understand any caveats about its interpretation. This includes information about the data source, the date(s) data were collected or the last update, and any notes that may affect any conclusions (e.g., data missingness, collection/sampling method).

Practice 6: Consider whether the visualizations support diversity, equity, and inclusion best practices.

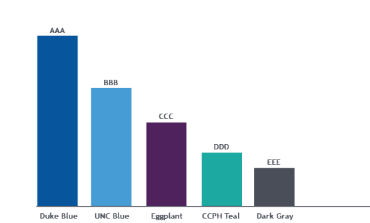
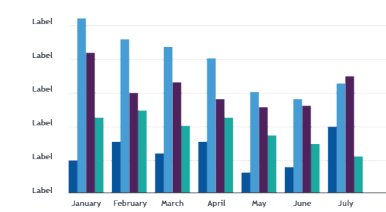
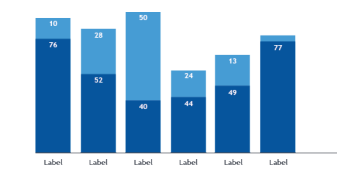
Often charts and dashboards have the goal of depicting differences in rates between priority populations and historically underserved groups. As stewards of the conversation around issues, challenges, and solutions affecting different groups, it is important it is important that graphic designers ensure language used in labels and headings follows inclusive language principles, and that labels, icons, and shapes do not reinforce historical stereotypes. Consider whether all groups are included in the data and if there are any groups that are missing. Be sure to clarify why particular groups are underrepresented in any text accompanying your charts and the implications for interpretation of the results. To the extent possible, include communities and people from your intended audience or from the audience of focus as reviewers throughout planning and development. This will ensure results take into account their lived experience. Additional considerations on this topic are included in the list of resources at the end of this document.

2. Overview of Data Visualization Types and Implementation

In this section we provide a quick reference for a variety of charts suitable for different types of data and storylines. This reference should help you compare and contrast different relevant charts side by side. After selecting the chart or charts you would like to consider, you can turn to the appropriate page later in the section dedicated to explaining how to design that particular type of chart. See section 3 for a detailed overview of each chart. *Note that this reference provides general guidance and should be seen as suggestions, not fixed rules. There are exceptions to the guidance, but be intentional when deviating from it.*

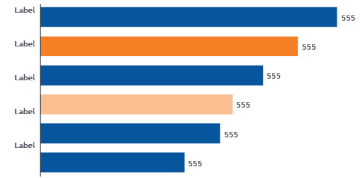
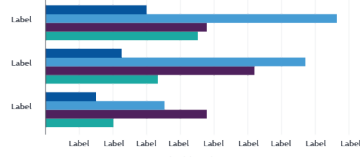
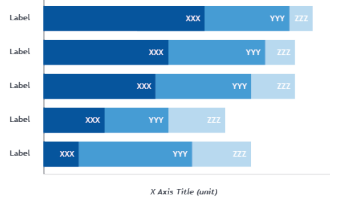
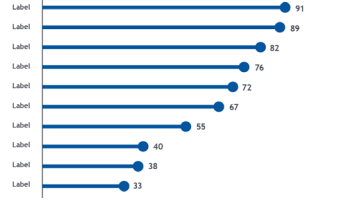
Ordinal Data

Comparison of categories or categorical subdivisions of measures with a natural ordering. Examples of “natural orderings” in data include data that vary across age groups, date ranges, income levels, and survey responses to Likert scale questions of the type “Strongly Disagree,” “No Opinion,” “Agree,” and “Strongly Agree.”

Visual Example	Chart Name and Use
	Column Charts are ideal for comparing a single measure across categories that have a natural ordering in the data.
	Clustered Column Charts are used when looking at an ordered response for different populations in the data or for different time periods.
	Stacked Column Charts can be used as an alternative to clustered column charts when the total is the key measure, but the part-to-whole information of subcategories is also of interest.

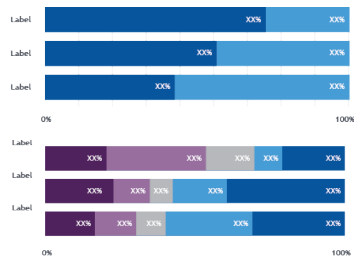
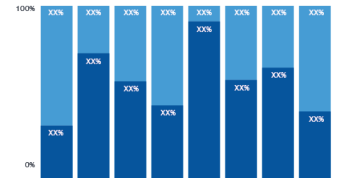
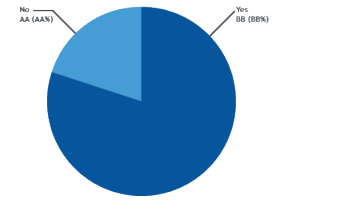

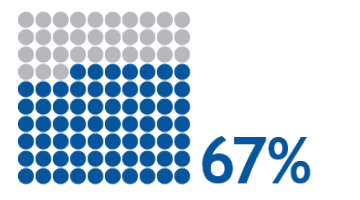
Nominal Data

Comparison of a measure across categorical subdivisions, where the category does not have a natural order. Examples of data without a natural category order include counts of an outcome or metric by unique persons, projects, or locations.

Visual Example	Chart Name and Use
	Bar Charts sorted by measure value are an ideal way to visualize nominal data to quickly understand relative ranking.
	Clustered Bar Charts are used to visualize nominal data that have hierarchical data levels (e.g., cases by region and race).
	Stacked Bar Charts can be used when there are natural subdivisions of a measure by category.
	Lollipop Charts combine the visual aspects of dot and bar charts to show comparisons of nominal values for a large number of categories or when space is limited.

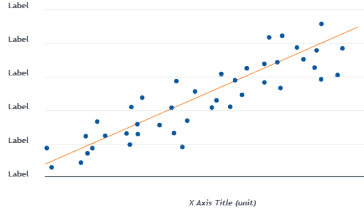
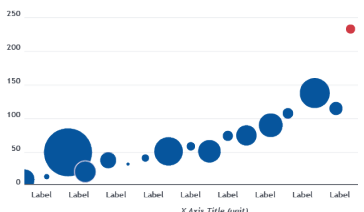
Proportions

Comparison of multiple different measures as ratios of a whole. These part-to-whole comparisons are focused on proportions, not absolute values.

Visual Example	Chart Name and Use
	100% Stacked Bar Charts are used to show the relative proportions (0%-100%) of subcategories within a category.
	100% Stacked Column Charts are a better option than 100% stacked bar charts when categories have some natural ordering.
	Pie Charts can offer variety and can be effective visuals to show the proportion of one or two categories.
	Treemaps can capture proportionality and hierarchical data structures for complex data with many categories.
	Waffle Charts are used to show percentages in a visual form.

Correlation

Comparison of two measures to determine how they are correlated.

Visual Example	Chart Name and Use
	Scatter Plots are used to visualize how two continuous measures are correlated.
	Bubble Charts are a useful variant of scatter plots when there is a third continuous measure of interest. The third measure is shown by the size of the “bubble.”

Tables and Numbers

Presentation of formatted numeric data or outcome highlights (numeric or qualitative).

Visual Example

Project #	State	Sum of Value 1	Sum of Value 2	Sum of Value 3
Project 1	Arizona	20	11,032	4
Project 2	Tennessee	33	4,536	4
Project 3	New Mexico	12	4,423	3
Project 4	Montana	25	9,738	6
Project 5	Florida	76	1,212	2
Project 6	Illinois	89	5,543	5
Project 7	Indiana	91	10,301	2
Project 8	Texas	12	1,300	7

Top Performing Project

Project 1

Best Practices

[Tables](#) are useful for presenting important related data elements from a dataset.

[Card Charts](#) can be used to show important metrics and key performance indicators.

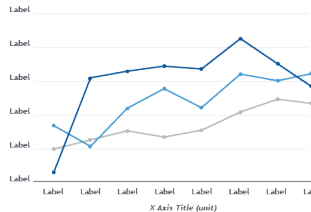
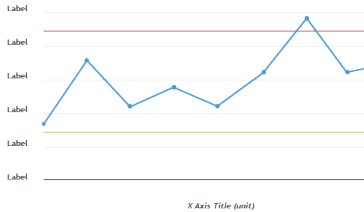
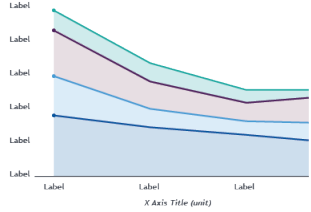
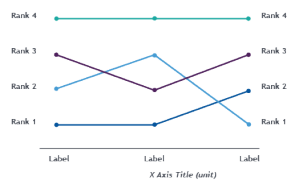
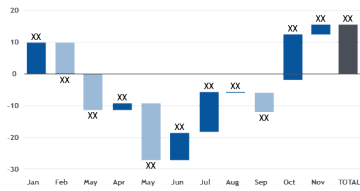
Benchmarking/Progress

Assessment of progress in one or more measures towards some benchmark or goal.

Visual Example	Chart Name and Use
	Bullet Charts are flexible visualizations that incorporate targets, benchmarks, and categories. They can be used to compare the same measure for multiple projects or separate measures within a given project.
	Gantt Charts are ideal for visualizing progress on projects or processes on a calendar scale that can be divided into multiple stages or phases.
	Progress Bar Charts are best used to highlight a single key metric.
	Donut Charts can be used to show “percentage complete.” The percentage value is shown at the center of the donut.
	Line Charts With Goal Line are used to show progress towards a goal over time.

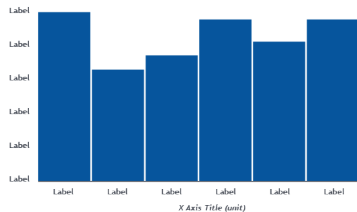
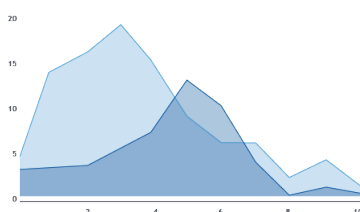
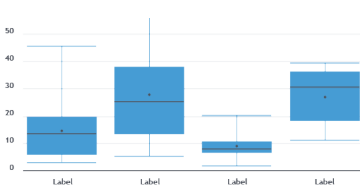
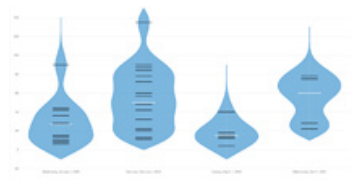
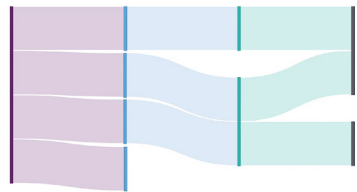
Time Series Data

One or more measures that vary over time.

Visual Example	Chart Name and Use
	Line Charts are used to display time series data in a way that allows viewers to discern trends and patterns.
	Line Charts With Control Lines are used to show time series data and identify spikes or valleys in the data that cannot be explained by ordinary variance.
	Area Charts can be used to show growth or distributional change in one measure over time.
	Bump Charts are a useful way to track rankings over time.
Column Chart	See Ordinal Comparison section for details.
	Waterfall Charts are useful for examining how a single quantity (e.g., total budget) changes over time as a result of additions or subtractions to the measure.

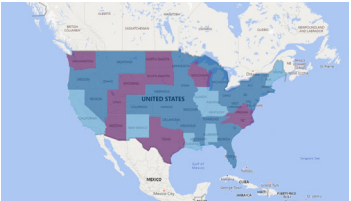
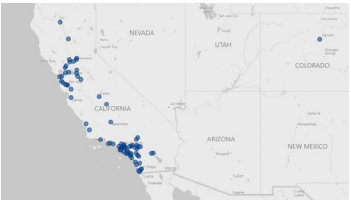
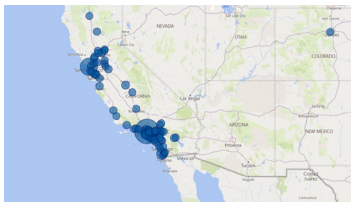
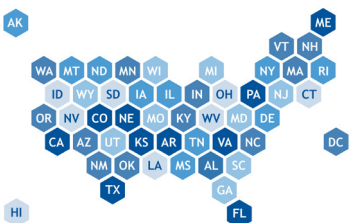
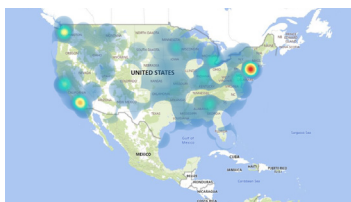
Distribution

Comparison of how one or two measures vary with respect to another.

Visual Example	Chart Name and Use
	Bar Histograms are best used when visualizing the distribution of one measure against bins that are applied to a related, continuous measure.
	Frequency Polygons can be used to compare the way two or more measures are distributed with respect to a binned, continuous variable.
	Box Plots show summary statistics on the distribution of a single measure over time or between nominal groups. Use box plots to communicate means, medians, interquartile ranges, and spreads of distributions.
	Violin Plots are used to visualize change in distribution over time, or compare distributions between different groups or projects.
	Sankey Diagrams are useful for visualizing how resources are distributed over time or within a system.

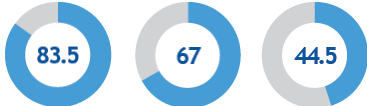
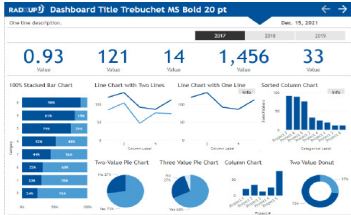
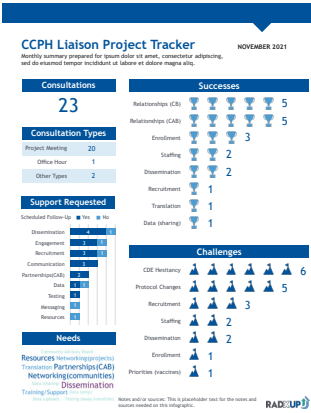
Geographic Data

Comparison of a single measure or multiple measures over a geographic region.

Visual Example	Chart Name and Use
	Choropleth Maps can be used to compare the values of both continuous and categorical measures across counties, districts, and states.
	Point Maps should be used when the data of interest are the locations of specific sites (e.g., location of testing sites).
	Bubble Maps are useful for data in which there are specific geographic points of interest (e.g., testing sites), as well as a measure associated with the points (e.g., number of tests administered).
	Hex and Tile Maps provide a way of visualizing data at the state and territory level that avoids “the Alaska problem,” which gives an outsized portion of map visualizations to large states like Alaska.
	Heat Maps should be used to track continuous variables (e.g., pollution level) at an extremely granular level.

Combining Multiple Visualizations

Often there is more to tell in a story than you can fit in one graphic. In these situations, consider one of the following approaches to combining multiple visualizations.

Visual Example	Chart Name and Use
	Small Multiples/Faceted Plots are used to break out the same statistic, time trend, or relationship between two variables by a third variable that has many groups. This is often used to show the same chart for multiple states, cities, or organizations.
	Dashboards can be used when you want to show multiple related charts and visualization types in one location. They are often used to show status or progress towards an issue overall, for each program in particular, and change in cases, health issue prevalence, or symptom growth over time.
	Infographics are used to tell a story about an issue using multiple visualizations. The data are typically representing a fixed period of time. The layout and graphical elements often organize charts meaningfully along the page to illuminate key data takeaways, changes over time, and data relationships. Graphics and statistics like counts may be demonstrated using representative icons counted out or filled up. These visual highlights provide memorable imagery for the intended audience. Qualitative quotes and narrative may be embedded within and between charts to add context and caveats to the data presented.

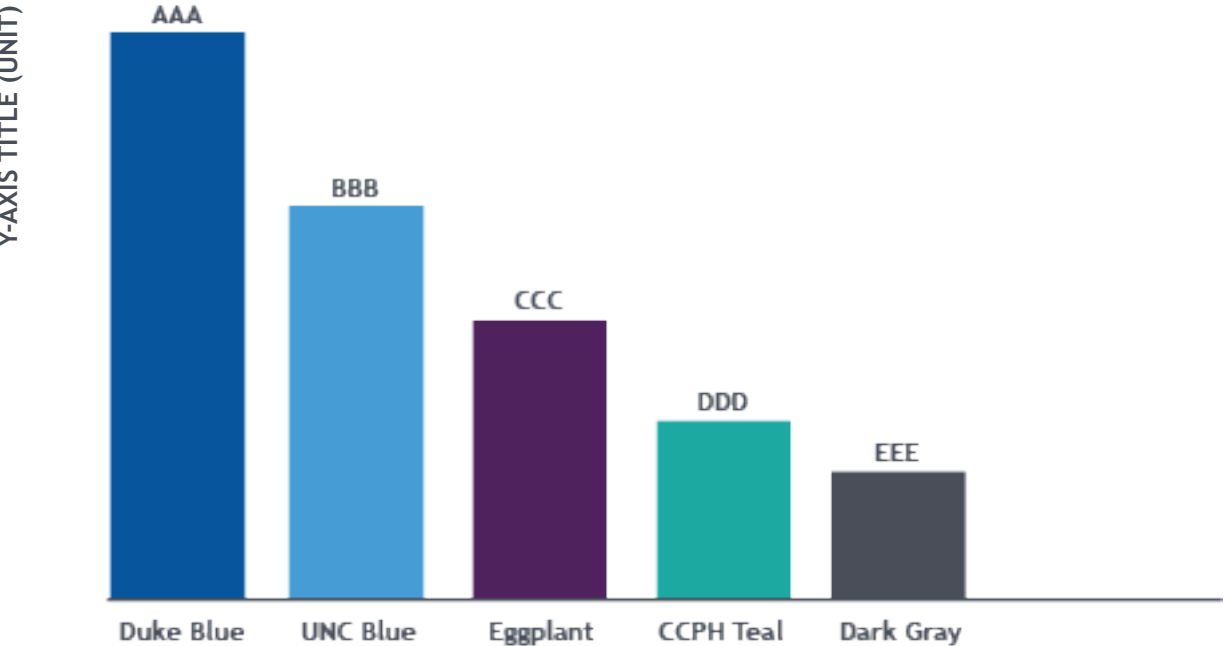
3. Implementation of Data Visualizations

ORDINAL DATA

Example 1 - Column Chart

Column Chart

Legend Title: ■ Label ■ Label ■ Label ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Column charts are ideal for comparing a measure (outcome) across categories where the data have a natural ordering, such as time or age. This is because readers process information presented left to right as sequential. An example includes comparing positive COVID-19 test results across different months or age groups.

Design Best Practices

Well-designed column charts communicate differences in values between categories quickly and accurately. To achieve this:

- Do not use 3D effects on column charts. 3D creates ambiguity about where the “top” of the column is.
- Start the y-axes at zero. With a zero baseline the reader can easily compare the column heights to one another to get a true sense of the value differences. Truncating the start of the axis can create deceptively large differences across columns even when the differences are small.
- Use an intentional sort order. Unknown, missing, not applicable, and other categories or subcategories are generally best positioned last, (i.e., right-most).
- Use direct data labeling when possible, placing the data labels outside the top of columns. That is, add the data value directly to each column rather than relying on axis values and gridlines to visually approximate the height of each column.

Axis and Gridlines

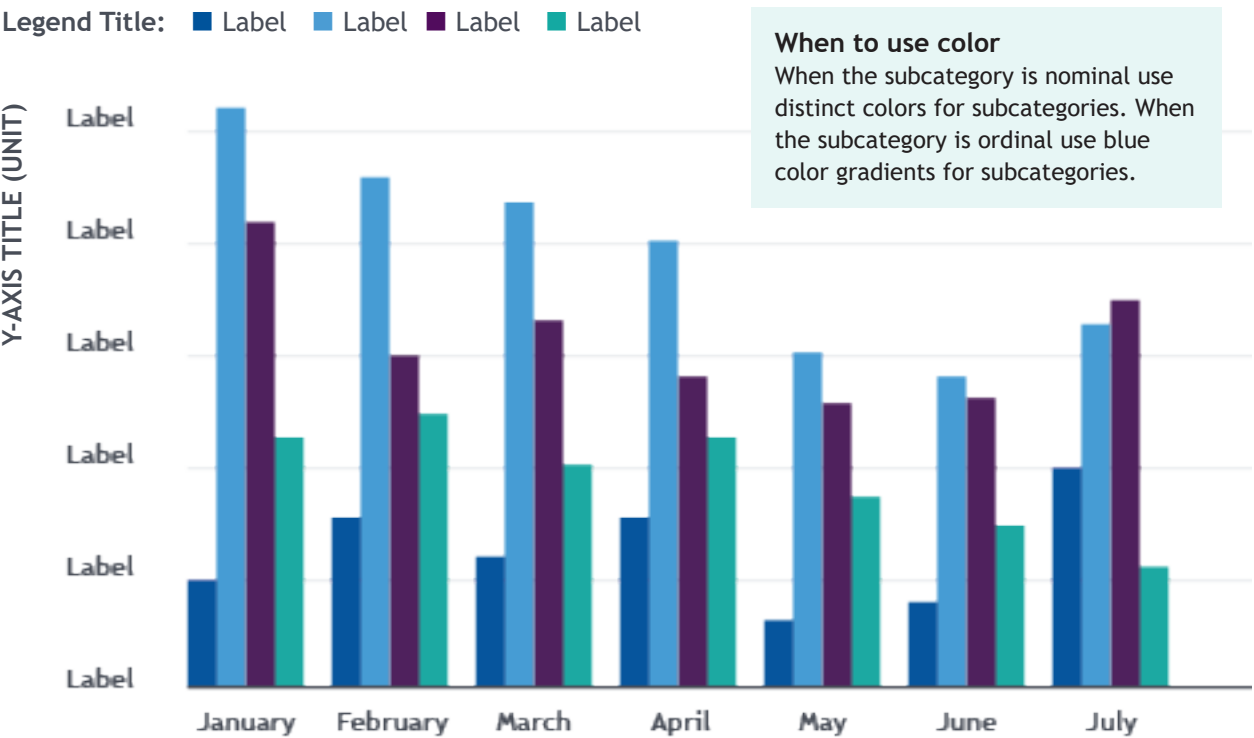
Use horizontal text for axis labels to maximize readability. If a category label is too long to fit horizontally within the x-axis, consider either using a shortened (abbreviated) version of the label (for example, using Sep. instead of September) or using a bar chart.

Column Spacing

Make the spacing between bars approximately one quarter to one third the width of the column.

Example 2 - Clustered Column Chart

Clustered Column Chart



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Clustered column charts are used when there are hierarchical data levels; that is, subcategories for each measure’s primary category. For example, examining the number of positive COVID-19 test results by age group (primary category) and race/ethnicity (subcategory). In this example, each cluster represents the distribution of positive test results by race, and each column represents the number of positive test results for a specific age group/race combination.

Design Best Practices

In addition to the column chart best practices there are specific considerations in designing clustered column charts.

- Base the choice of which category should be the primary x-axis (defining the clusters) and which should be the “secondary” x-axis (defining specific columns) on which data relationship and comparison will be most important to highlight for the reader.
- Select the category with natural ordering as the primary category. For example, if the primary category of interest is distributions of positive test results by race within a specific age group, a clustered column chart is appropriate. If the opposite is desired (i.e., distributions of positive test results by age group within a specific race), a clustered bar chart may be a better choice.

Axis and Gridlines

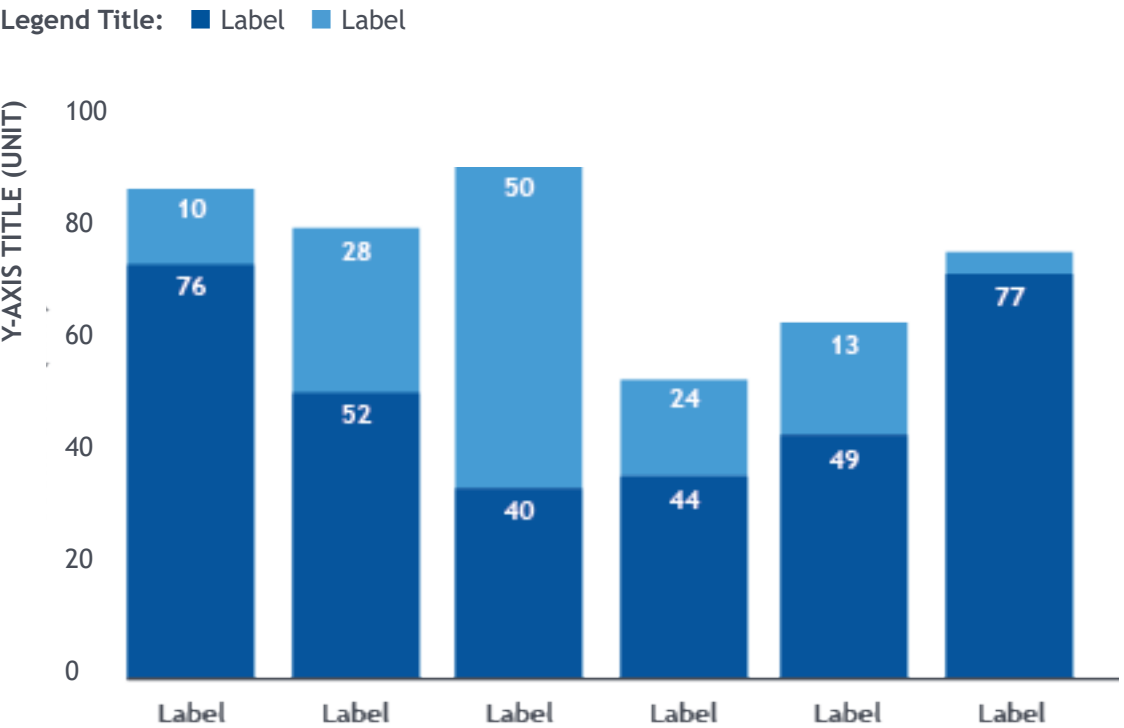
Use horizontal text for x-axis labels to maximize readability. If a category label is too long to fit horizontally within the x-axis, consider either using a shortened (abbreviated) version of the label (for example, using Sep. instead of September) or using a bar chart.

Column Spacing

Make the spacing between clusters approximately one quarter to one third the width of the cluster. If the software allows, consider using a small space between subcategory bars.

Example 3 - Stacked Column Chart

Stacked Column Chart



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Stacked column charts can be used as an alternative to clustered column charts when the primary focus of the chart is the total value of the primary category, but the relative contributions of the subcategories are also of interest. Stacked column charts are meant to capture the raw value of a measure. If the proportionality of subcategories is the primary outcome of interest, a better choice is a 100% stacked column chart or 100% stacked bar chart.

Design Best Practices

In addition to the column chart best practices, there are specific considerations in designing stacked column charts.

- Keep the number of subcategories to three or fewer per column (more categories can sometimes be used but is discouraged).
- Order subcategories consistently across the chart, that is, each column should have the same subcategory and color ordering.
- Be intentional about the subcategory order. For ordinal subcategories, use the natural order. For nominal subcategories place the most important subcategory closest to the x-axis because this will be the easiest to compare across the chart.
- Display the total for each bar above the bar.
- Start the y-axis at zero.
- Do not use a stacked column chart if comparing the values of multiple subcategories is important. When subcategories are stacked, only the bottom value has a uniform baseline at zero; the rest have different starting values that depend on the height of the lower segments. Because of this, the heights of the upper subcategory segments are more difficult to compare across the columns. Use a clustered bar chart instead or consider creating both a bar chart and clustered bar chart to display both the total by category and also be able to compare subcategories accurately. An example of when to use a clustered bar chart instead of a stacked column chart is comparing the monthly number of COVID test by urban/suburban/rural regions because it is important to see the change from month to month of all three regions individually.

Color

When a color legend is used, order the legend items to align with the subcategory order of the column; and, when practical, also align the legend orientation (that is, stack the subcategories in a column with one item per row, rather than all items in a single row).

Axis and Gridlines

Use horizontal text for axis labels to maximize readability. If a category label is too long to fit horizontally within the x-axis, consider either using a shortened (abbreviated) version of the label (for example, using Sep. instead of September) or using a bar chart.

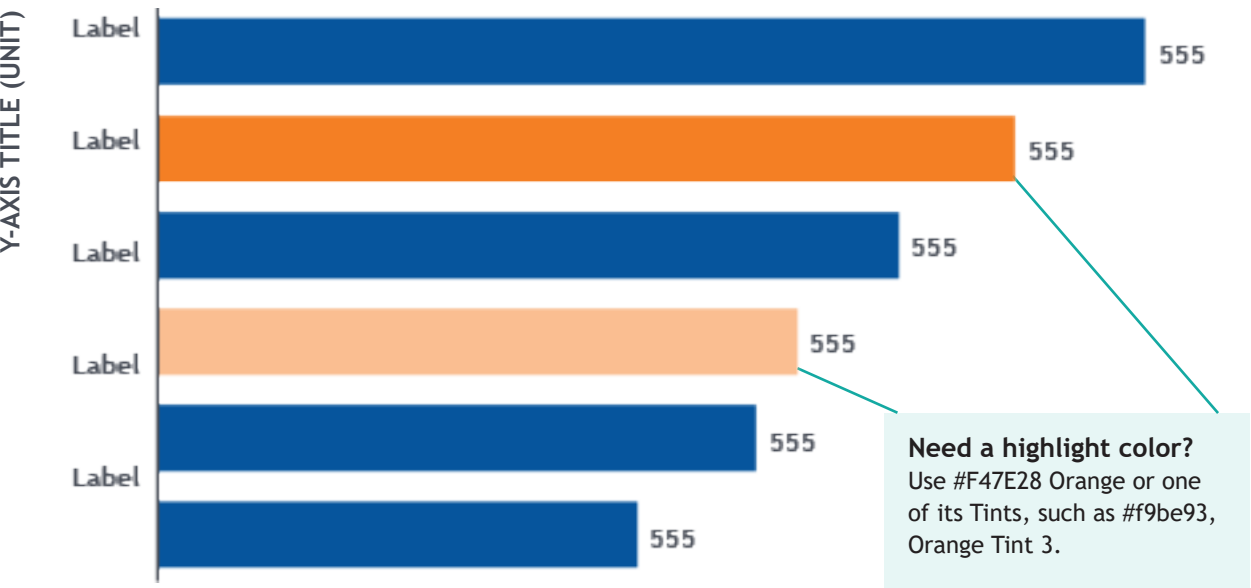
Column Spacing

Make the spacing between bars approximately one quarter to one third the width of the column.

Example 4 - Bar Chart

Bar Chart, Two Highlighting Options

Legend Title: ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Bar charts sorted by measure value are an ideal way to visualize nominal data to quickly understand relative ranking. Readers process information from top to bottom, so picking a proper sort (ascending or descending by measure) will define the purpose of the chart (highlighting low or high values of the measure). The bars in a bar chart can be as thin as one line of text and can be a good alternative to a column chart when there are a large number of categories.

Design Best Practices

- Well-designed bar charts communicate differences in values between categories quickly and accurately. To achieve this:
- Do not use 3D effects on bar charts. 3D creates ambiguity about where the “end” of the bar is.
 - Start the x-axis at zero, so that the reader can easily compare the lengths of the bars to one another to get a true sense of the value differences. Truncating the start of the axis can create deceptively large differences across bars even when the differences are small.
 - Use an intentional sort order. Unknown, missing, not applicable, and other categories or subcategories are generally best positioned last, (i.e., bottom-most).
 - Use direct data labeling when possible, placing the data labels outside the end of bars. That is, add the data value directly to each bar rather than relying on axis values and gridlines to visually approximate the length of each bar.

Axis and Gridlines

Bar charts allow for long horizontal categorical labels, which is ideal for user readability. This may be a reason to use a bar chart instead of a column chart, even for ordinal data.

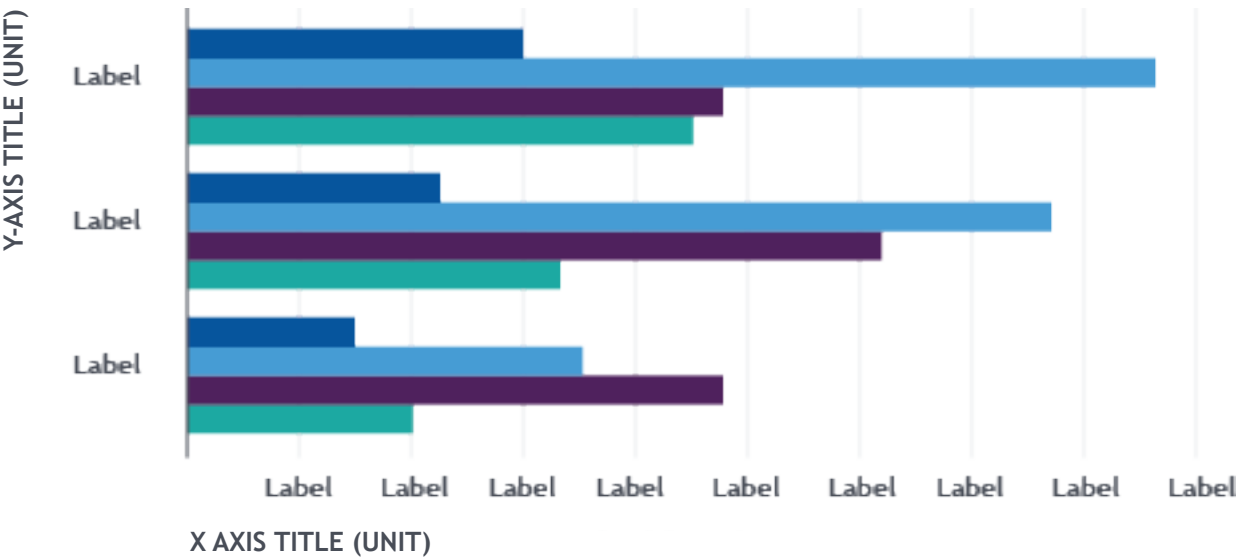
Bar Spacing

Make the spacing between bars approximately half the width of the column.

Example 5 - Clustered Bar Chart

Clustered Bar Chart

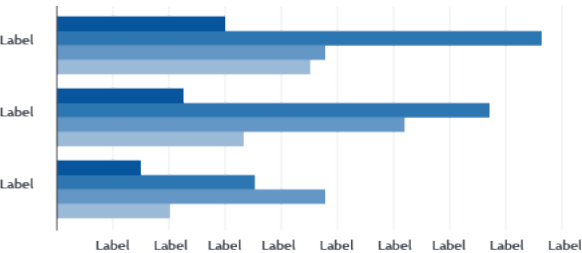
Legend Title: ■ Label ■ Label ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Alternate color scheme:



Clustered bar charts are used when there are hierarchical data levels. Similar to using a clustered column chart, order the primary category and subcategories intentionally. An example would be examining the number of positive COVID-19 test results by region and race/ethnicity.

Design Best Practices

In addition to the bar chart best practices, there are specific considerations in using clustered bar charts.

- Base the choice of which category should be the primary variable (defining the clusters) and which should be the secondary variable (the subcategories defining specific bars) on on which comparisons or bar arrangements will be most important to highlight for the reader.
- Order the clusters and subcategories intentionally.
- Select the category with natural ordering as the secondary variable, (i.e., the cluster subcategory). For example, if the outcome of interest is the distributions of positive test results by age group (cluster subcategory) within a specific race (cluster category), a clustered bar chart is appropriate. If the opposite is desired (i.e., distributions of positive test results by race within a specific age group), a clustered column chart may be a better choice.

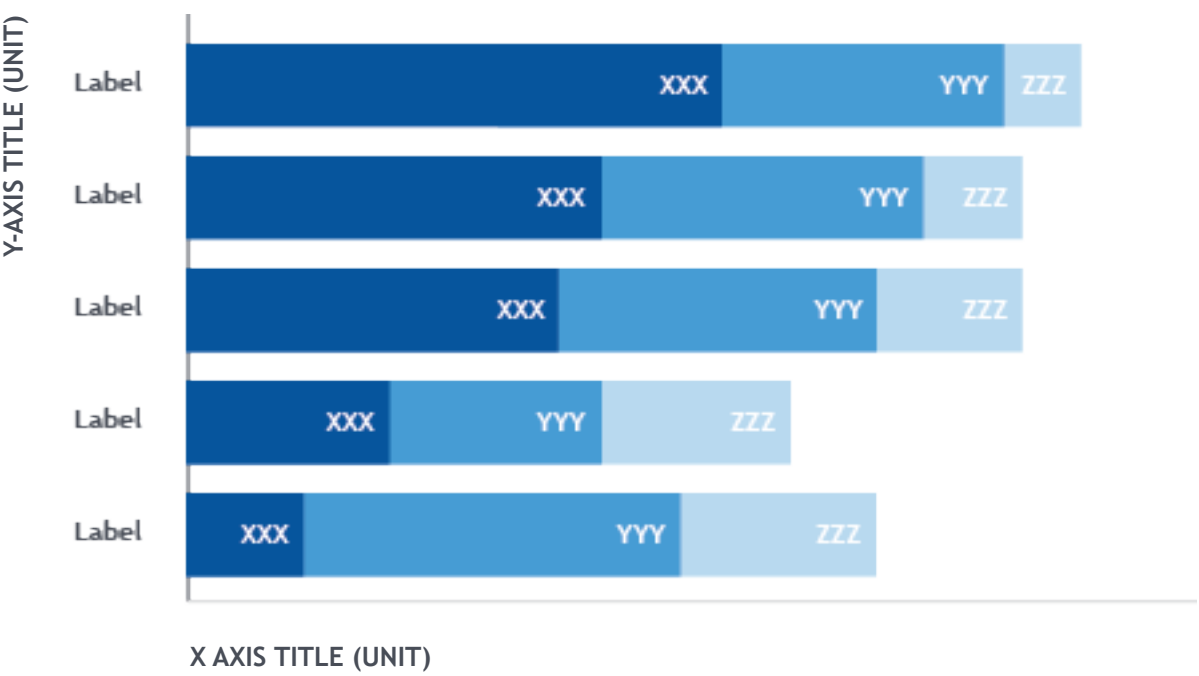
Axis and Gridlines

Clustered bar charts allow for long categorical labels horizontally, which is ideal for user readability. This may be a reason to use a clustered bar chart instead of a clustered column chart, even for ordinal data.

Example 6 - Stacked Bar Chart

Stacked Bar Chart

Legend Title: ■ Label ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Stacked bar Charts can be used as an alternative to clustered bar charts when the primary focus of the chart is the total value of the primary category, but the relative contributions of the subcategories are also of interest. Stacked bar charts are meant to capture the raw number of a measure. If the proportionality of subcategories is the primary outcome of interest, a better choice is a [100% stacked bar chart](#) or [100% stacked column chart](#).

Design Best Practices

In addition to the bar chart best practices there are specific considerations in designing stacked bar charts.

- Keep the number of subcategories to three or fewer per bar (more categories can sometimes be used but is discouraged).
- Order subcategories consistently across the chart—that is, each bar should have the same subcategory and color ordering.
- Be intentional about the subcategory order. For ordinal subcategories, use the natural order. For nominal subcategories, place the most important subcategory closest to the y-axis, because this will be the easiest to compare across the chart.
- Do not use a stacked bar chart if the value of multiple subcategories is important. Use a clustered bar chart instead or consider creating both a bar chart and clustered bar chart to both display the total by category and compare subcategories accurately.
- To ease interpretation, the axis should always start at zero, and each section of the bar should be labeled with total counts for the represented category.

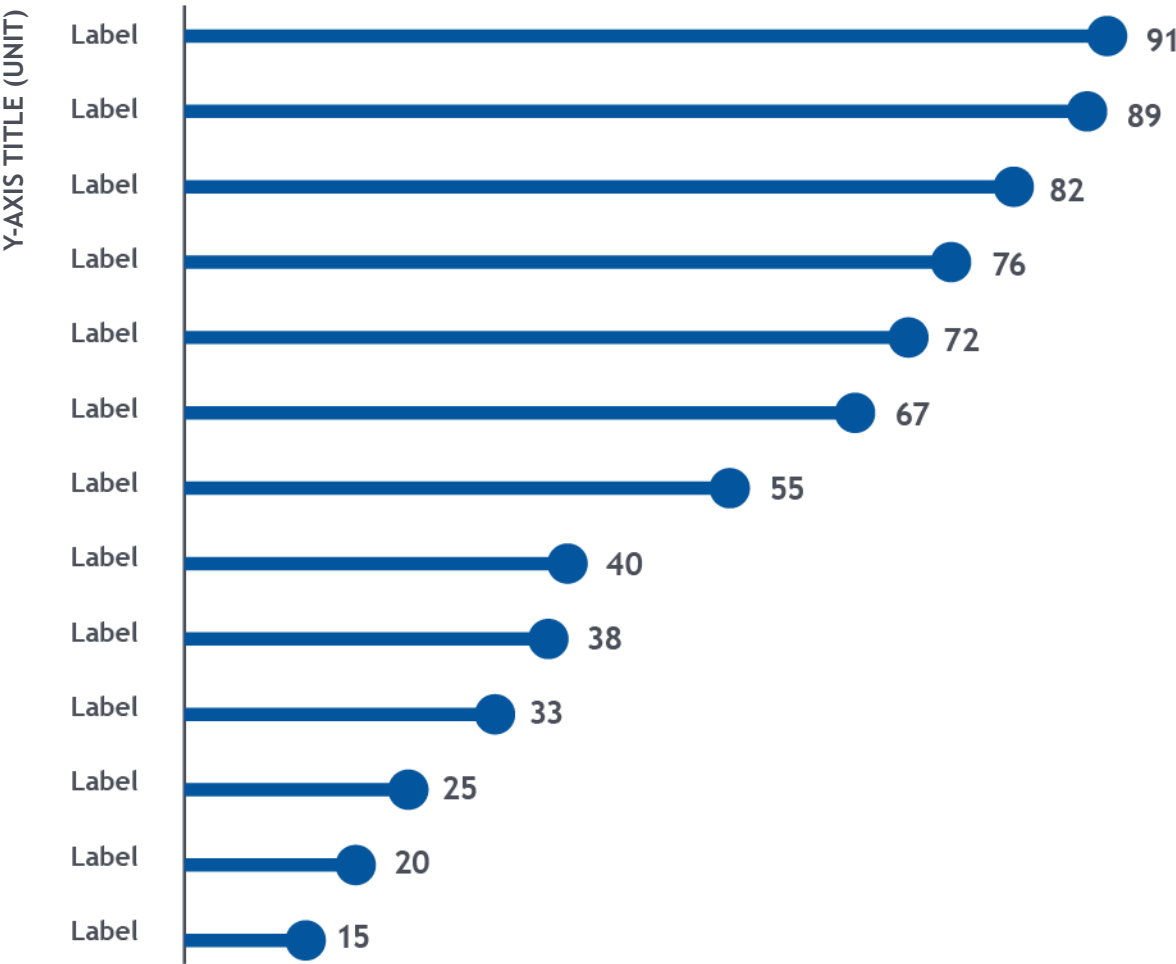
Bar Spacing

Make the spacing between bars approximately half the width of the column.

Example 7 - Lollipop Chart

Lollipop Chart

Legend Title: ■ Label ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Lollipop charts combine the visual aspects of dot and bar charts to show comparisons of nominal values for a large number of categories. Common chart content includes topics you would like to rank. In comparison to bar charts, lollipop charts lend a lighter visual profile to each category of information, which can make them more aesthetically pleasing than bar charts by adding more white space. Readers process information from top to bottom, so picking a proper sort (ascending or descending by measure) will define the purpose of the chart (highlighting low or high values of the measure). To guide readers through the data, lollipop dot colors can be changed to highlight values for a particular group (e.g., the value for a group of interest, the greatest value) or to highlight or visually connect groups of dots (e.g., grouping all cities in the same state with the same color dot). Size of the dot can also be used to group values, but users should be mindful to not modify the dot size to such an extent that the length of the bar is markedly changing or overlapping with adjacent dots.

Lollipop charts can also be useful for showing percent change, with lines extending above and below the x-axis to capture change over time for a larger number of categories.

Design Best Practices

Well-designed lollipop charts communicate differences in values between categories quickly and accurately. To achieve this:

- Start the x-axis at zero, so that the reader can easily compare the lengths of the bars to one another to get a true sense of the value differences. Truncating the start of the axis can create deceptively large differences across bars even when the differences are small.
- Use an intentional sort order. Unknown, missing, not applicable, and other categories or subcategories are generally best positioned last, i.e., right-most or at the bottom.
- Use direct data labeling when possible, placing the data labels outside the end of bars. That is, add the data value directly to each dot rather than relying on axis values and gridlines to visually approximate the length of each bar.

Axis and Gridlines

Lollipop charts allow for long horizontal categorical labels, which is ideal for user readability. This may be a reason to use a bar chart instead of a column chart, even for ordinal data.

Lollipop Spacing

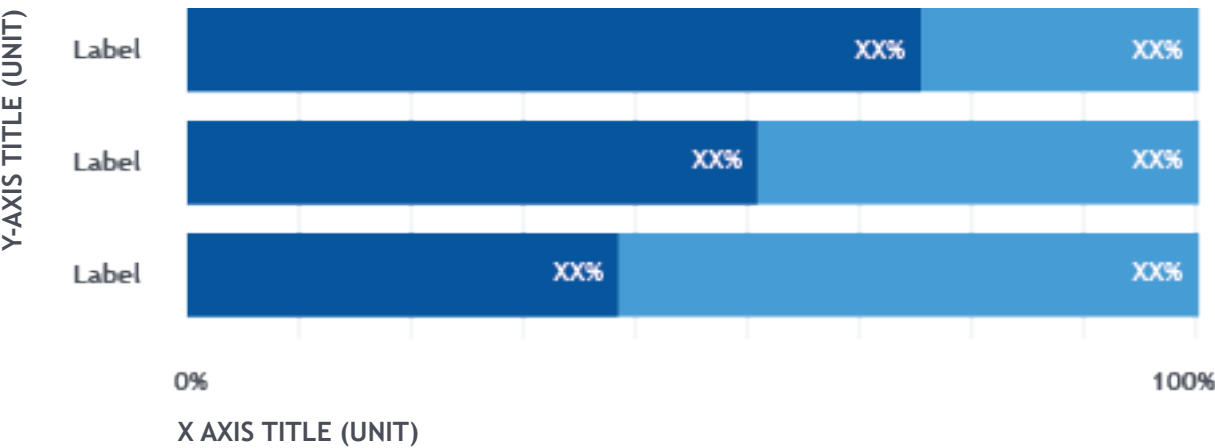
Make the spacing between lines approximately half the width of the column.

PROPORTIONS

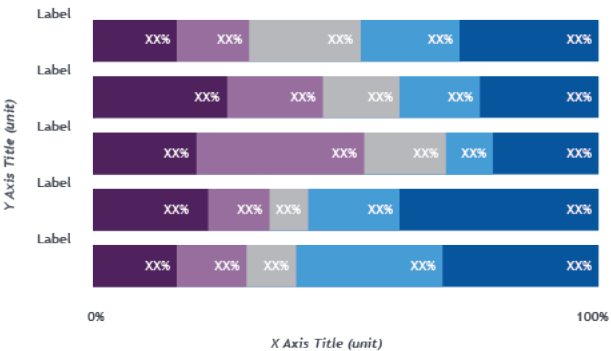
Example 8 - 100% Stacked Bar Chart

100% Stacked Bar Chart

Legend Title: ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



100% stacked bar charts are used to show the relative proportions (0%-100%) of subcategories within a category. If the raw number of measures within subcategories is the primary outcome of interest, a better choice is a stacked bar chart or stacked column chart.

Design Best Practices

In addition to the bar chart best practices, there are specific considerations in designing 100% stacked bar charts.

- Keep the number of subcategories to three or fewer, unless the subcategories are based on a Likert scale. A greater number of categories is discouraged. If there are more than three categories not based on a Likert scale, consider whether the subcategories can be grouped into three or fewer. If a greater number of subcategories is needed, consider using a clustered bar chart instead.
- Order subcategories consistently across the chart—that is, each column should have the same subcategory and color ordering.
- Be intentional about category sort order (i.e., how the bars should be ordered from top to bottom in the chart).
- Be intentional about the subcategory order (i.e., how the subcategory segments should be ordered from left to right with a bar). For ordinal subcategories such as a Likert scale, use the natural order by placing the disagreement subcategories closest to the y-axis (e.g., Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree).

Color

When the subcategories are defined by a Likert scale (or similar type of data), color can be used differentiate between negative, neutral, and positive groupings. Use different colors for negative, neutral, and positive responses. Use shading for the degree of positivity/negativity to emphasize this difference, as in the example visual.

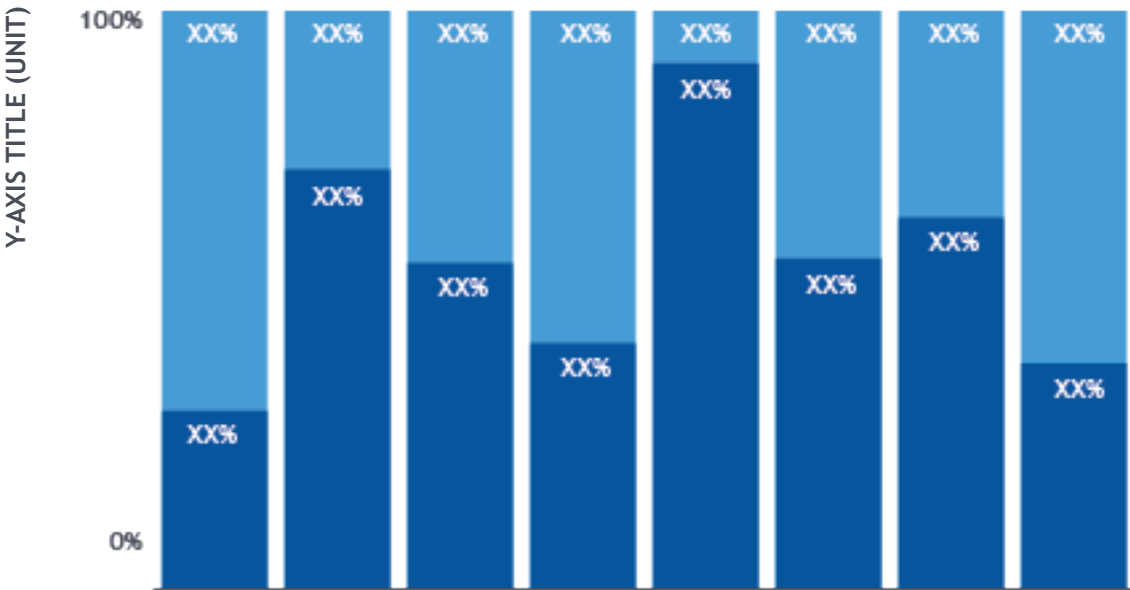
Axis and Gridlines

Axis and gridlines can be helpful for 100% stacked bar charts even when direct data labels are used. Showing the 0% to 100% range reinforces that the percentage data labels are the fractions of the category total. However, axes and gridlines can be omitted to simplify the image, allowing the reader to focus on the content in the chart. The reader will interpret the bar as beginning at 0% and ending at 100% from the labeling and title.

Example 9 - 100% Stacked Column Chart

100% Stacked Column Chart

Legend Title: ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



100% stacked column charts are used to show the relative proportions (0%-100%) of subcategories within a category. If the raw number of measures within subcategories is the primary outcome of interest, a better choice is a stacked bar chart or stacked column chart. Use a 100% stacked column chart if the values of the primary categories have a natural ordering.

Design Best Practices

In addition to the column chart best practices, there are specific considerations in designing 100% stacked column charts.

- Keep the number of subcategories to three or fewer. A greater number of categories is discouraged. If there are more than three categories, consider whether the subcategories can be grouped into three or fewer. If a greater number of subcategories is needed, consider using a clustered column chart instead.
- Order subcategories consistently across the chart—that is, each column should have the same subcategory and color ordering.
- Be intentional about the subcategory order. If subcategories are ordinal, use the natural ordering. If subcategories are nominal, the subcategory of most interest should be closest to the x-axis, as that will be the easiest column segment to compare across the categories.

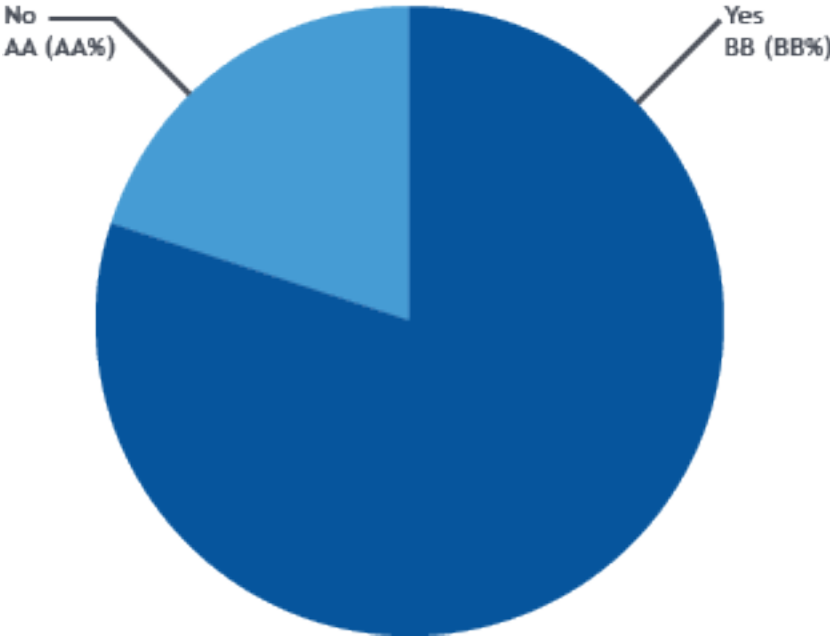
Axis and Gridlines

Axis and gridlines can be helpful for 100% stacked column charts even when direct data labels are used. Showing the 0% to 100% range reinforces that the percentage data labels are the fractions of the category total. However, axes and gridlines can be omitted to simplify the image, allowing the reader to focus on the content in the chart. The reader will interpret the bar as beginning at 0% and ending at 100% from the labeling and title.

Example 10 - Pie Chart

Pie Chart

Legend Title: ■ Label ■ Label



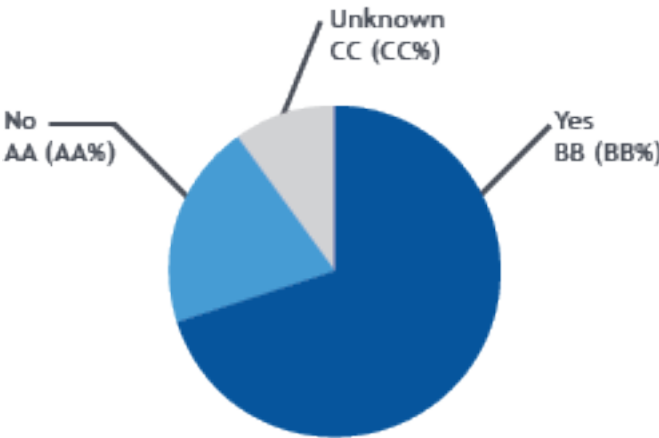
Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Pie charts can offer variety and can be effective visuals when showing one or two categories. Small multiples can be an effective use of the pie chart, (e.g., by showing the proportion of positive COVID-19 results by region with a series of small regional pie charts).

Design Best Practices

- Use pie charts to show proportions of one or two categories. At most, three categories can be okay under some circumstances, (e.g., “Yes”, “No”, and “Unknown” as answers to a survey question). More than three categories become hard to interpret in a pie chart and a bar chart is a preferred.
- Use direct labeling as shown in the example, with the category, percentage value, and raw value.
- Order the wedges intentionally, with the primary category of interest first starting from the 12 o’clock position, and present other categories in a clockwise direction.



Example 11 - Treemap

Treemap

Legend Title: ■ Label ■ Label ■ Label ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Treemaps are primarily used to display data that are grouped and nested in a hierarchical (or tree-based) structure to capture proportionality (0%-100%).¹ Treemaps are composed of rectangular blocks called “leaves” that are color coded to distinguish from one another. They are best used when a global picture of composition is desired, without a need for direct or precise comparison. If there are a relatively small number of categories, if the categories are ordinal, or if a direct and precise comparison is needed, consider using a clustered bar chart or column chart instead.

A natural use case for treemaps would be examining the proportions of different types of COVID-19 tests that have been administered by a project. The color of a leaf will communicate the type of a test and the size of the leaf indicates the proportion of tests of this type compared to the total number of tests administered. If there are sub-types of tests within a given test type, these sub-types can be added to the Detail tab of the visualization to show how these sub-types are distributed within an overarching type.

Design Best Practices

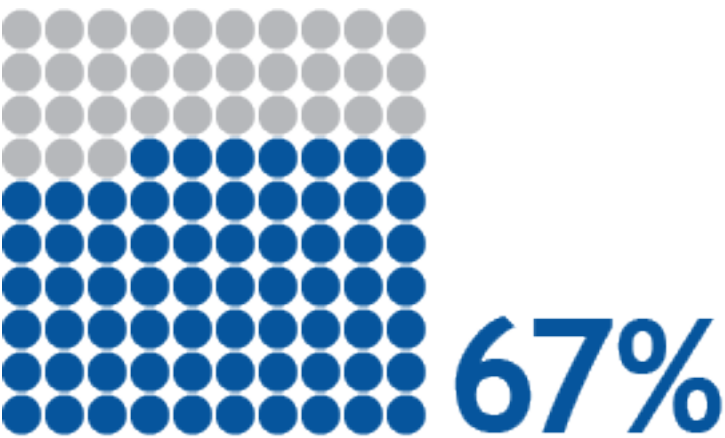
- Directly label the leaves of the treemap where possible. Use horizontal text for the category labels to maximize readability.

¹ Tree maps are also used in qualitative research to map a hierarchy of ideas or relationships between activities or organizations in a system. The process for collecting and distilling data for qualitative tree maps are not discussed in this guide.

Example 12 - Waffle Chart

Waffle Chart

Legend Title: ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Waffle charts are used to show percentages and are used in place of bar charts. Because of their small size and simplicity they are a good candidate for a small-multiples visual when you would like to report proportions for a larger number of categories (more than five). They can be used when you are tracking an activity towards completion (trying to fill up the full waffle block) or when you are comparing activities that are variable in value intrinsically (making comparison of two bar chart lines unnecessary).

Each colored dot indicates a proportion of the whole waffle block. Blocks with more colored dots have higher proportions. A natural use case for waffle charts within a COVID-19 context could be proportions of patients presenting for testing with each potential symptom, or the proportion of patients self-reporting a barrier to care or a reason for referral to care. These types of charts can help decision makers and clinicians identify needs or prevalent issues within their patient population or community.

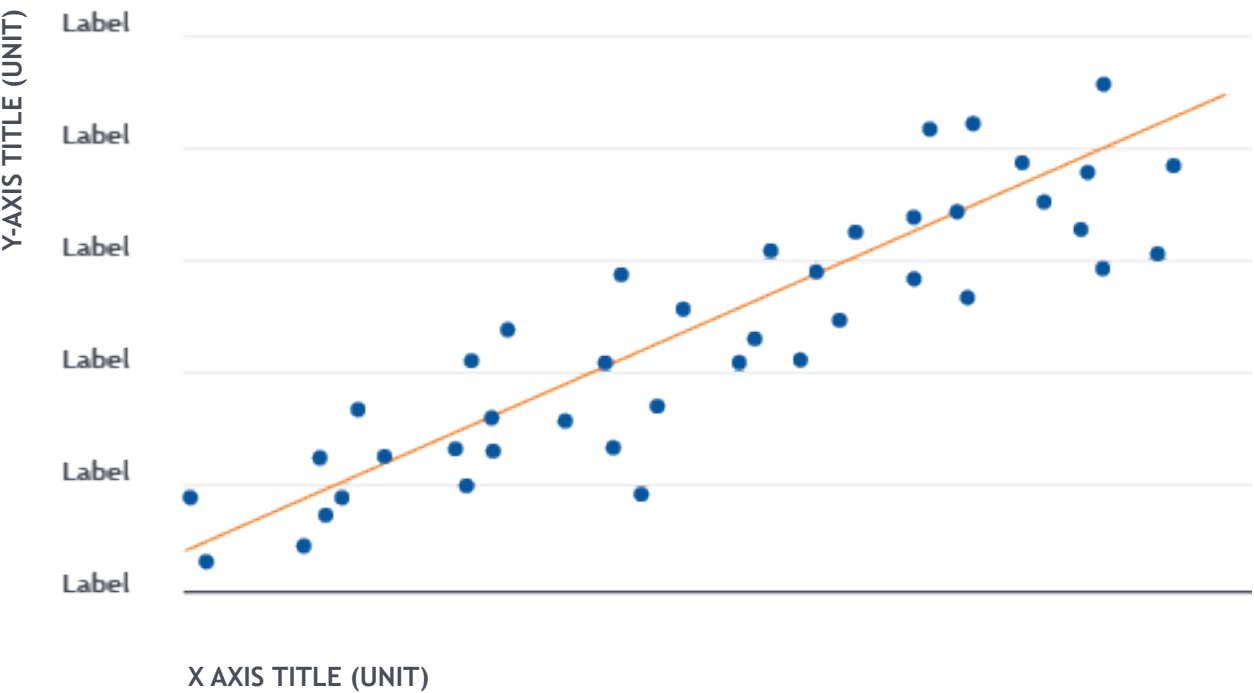
Design Best Practices

- Directly label the chart with the percentage in a font size larger than the label text.
- If used in small multiples, organize the charts alphabetically or group items you would like to compare together.
- Use horizontal text for the category labels to maximize readability.

Example 13 - Scatter Plot

Scatter Plot

Legend Title: ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Scatterplots are used to display how two continuous numerical measures are correlated.

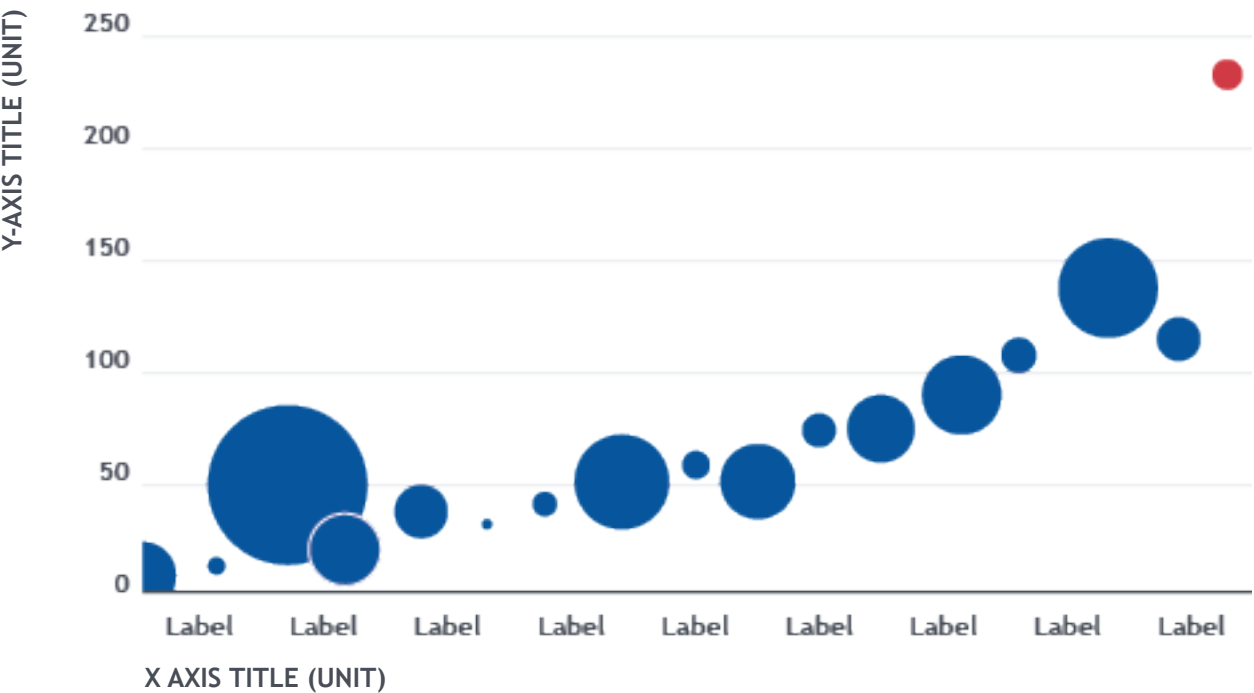
Design Best Practices

- Equally space axis intervals.
- Choose axis start and end points judiciously to highlight the specific correlation that is displayed.
- If a scatter plot is plotted on a log or log-log scale, place this information in either the title of the chart or in the axis titles.

Example 14 - Bubble Chart

Bubble Chart

Legend Title: ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Bubble charts can be used in lieu of scatter plots if there is a third continuous measure of interest, with the third measure represented by the size of the point on the graph, (i.e., the bubble size). For example, in addition to showing how the sensitivity and specificity of COVID-19 tests are correlated in a scatter plot, incorporate a third variable about how many types of tests there are in each specificity/sensitivity category. This can be accomplished by varying the bubble size corresponding to how many tests fall into a specificity/sensitivity combination.

Design Best Practices

- Equally space axis intervals. Choose axis start and end points judiciously to highlight the specific correlation that is being displayed.
- If a bubble chart is plotted on a log or log-log scale, place this information in either the title of the chart or in the axis titles.

Example 15 - Table

Table

Project # ▲	State	Sum of Value 1	Sum of Value 2	Sum of Value 3
Project 1	Arizona	20	11,032	4
Project 2	Tennessee	33	4,536	4
Project 3	New Mexico	12	4,423	3
Project 4	Montana	25	9,738	6
Project 5	Florida	76	1,212	2
Project 6	Illinois	89	5,543	5
Project 7	Indiana	91	10,301	2
Project 8	Texas	12	1,300	7

Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Tables are used to present data in a “raw” format. Use tables to show mixed categorical and numerical data that a reader can use to explore the data. Tables allow more variables to be shown together than charts do. With interactive dashboards, tables can be leveraged to drill down (expand the level of detail) for additional granularity or roll up (collapse the level of detail) to get summary statistics (sum, mean, median, etc.).

Design Best Practices

- Alternate the colors of data rows in a table to break up the table. This practice improves readability and is known as “zebra-striping.”
- If possible, size the table so that all data are visible without scrolling.
- Avoid using borders and gridlines to focus the reader on the text.

Color

Color is used to highlight data points of interest or to communicate Key Performance Indicators relevant to the data. Use the indicator colors in the Data Visualization Colors section to color the cells of numerical data when you wish to convey information like “above/ below threshold.” Gradients can also be used for continuous numerical measures that are present in your table. Use darker colors to highlight data points, as these will draw users’ attention and serve as a more effective highlight.

Axis and Gridlines

Column gridlines are not generally needed, and distract from the information in the table. Only use gridlines to break up the columns of your table intentionally. The “zebra striping” color scheme recommended naturally breaks up rows, alleviating the need for row gridlines.

Example 16 - Card Chart

Card Chart

Legend Title: ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Card visuals are used to draw attention to important single values with oversized font. They are a highlight visual that displays a single important data point that is often relevant to a dashboard’s theme. Cards can be effective by themselves, or multiple cards can be arranged adjacent to one another to communicate a series of key metrics. Use cards to display information such as summary statistics, Key Performance Indicators, or top performing projects/sites.

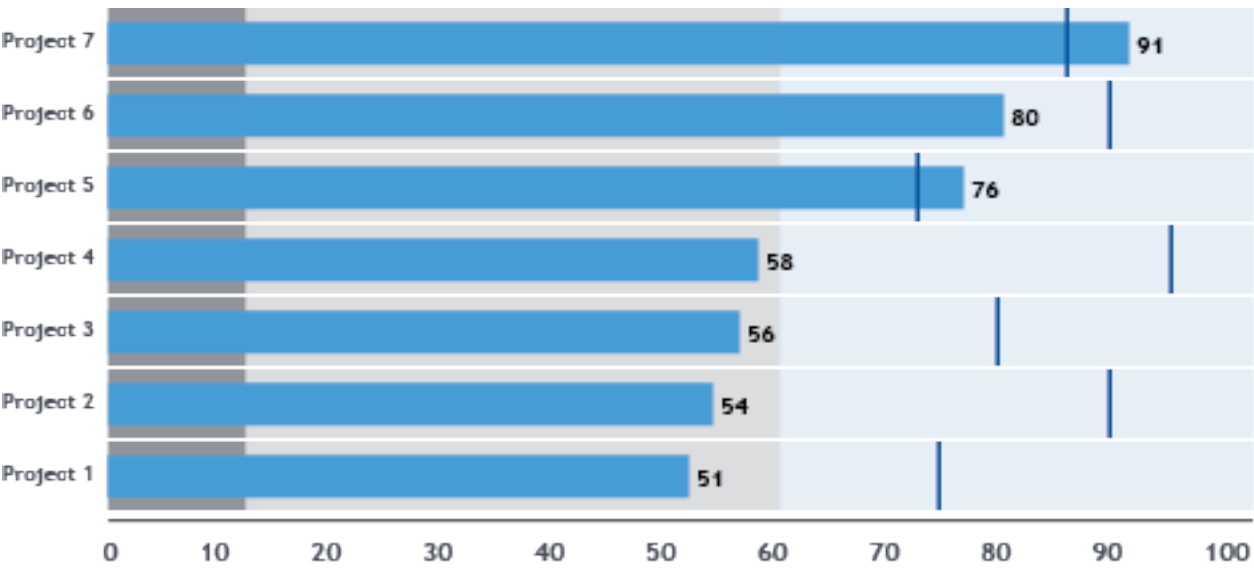
Design Best Practices

- Always clearly title card visuals. A single number or string of text without context is confusing and unclear. Do not use cards unless the information in them can be given a simple and easy-to-understand title.
- Use consistent font sizing throughout a dashboard.
- Consider using color to highlight when a value is below/above a goal or benchmark (e.g., red/green).

Example 17 - Bullet Chart

Bullet Chart

Legend Title: ■ Label ■ Label ■ Label ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



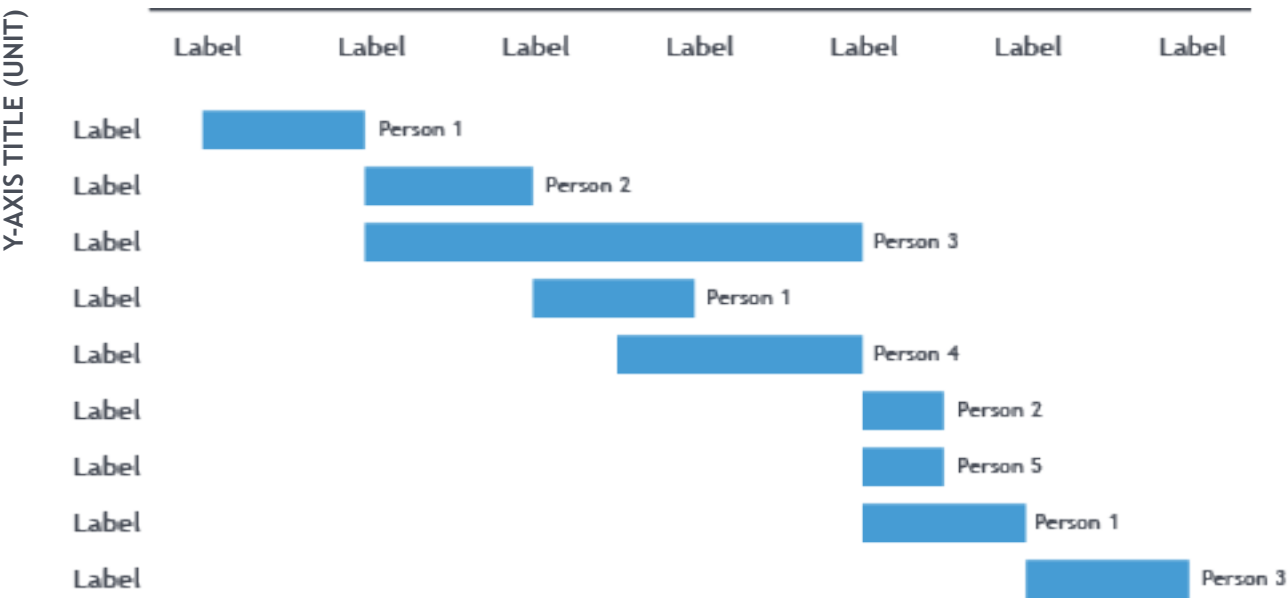
Bullet charts are a flexible visualization that allows designers to specify targets, benchmarks, and categories such as “Satisfactory,” “Good,” “Behind Target,” or “Current,” “Prior,” and “Target.” This makes them ideal for visualizing progress towards goals, and to highlight challenge areas for different projects. They can be used to compare the same measure for multiple projects, or separate measures within a given project.

A use case for bullet charts is tracking the number of COVID-19 tests administered by project, with reference to specific goals that projects have regarding their number of tests.

Example 18 - Gantt Chart

Gantt Chart

Legend Title: ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Gantt charts are used to visualize progress on projects or processes on a calendar scale that can be divided into multiple stages or phases. Use a Gantt chart to assign tasks to individuals and effectively communicate timelines and goals.

Design Best Practices

- Include the person or team that a task is assigned to as a label next to the task bar. All labels should be horizontal to maximize readability.
- Put start and end dates for the task in the tooltip.

Color

Color may also be used intentionally to highlight different categories of task (e.g., design, development, quality control). Since qualitative differences in tasks are nominal, use the full color palette as indicated in the Data Visualization Colors section.

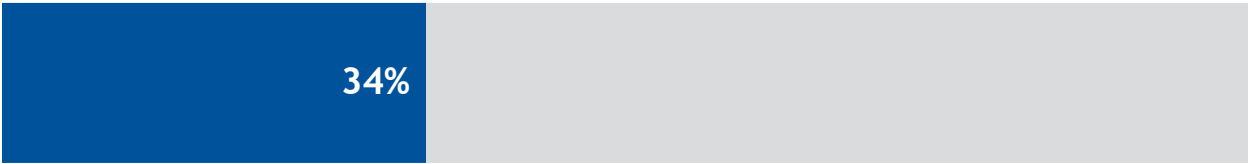
Axis and Gridlines

Place the date axis at the top of the visualization and pick an appropriate scale for it based on the total timeline of the project being visualized. Use gridlines to separate different blocks of tasks.

Example 19 - Progress Bar Chart

Progress Bar Chart

Legend Title: ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Progress bar charts show progress towards a goal when the outcome can be measured by percent complete.

Design Best Practices

- Include the “percent complete” label in the inside end of the blue portion of the bar.
- Maintain consistent sizing if more than one progress bar is used.
- Use a progress column (a vertical version of the progress bar) in place of a progress bar based on the availability of dashboard space and the general dashboard design.

Axis and Gridlines

To avoid cluttered charts, consider not including x-axis or only including the 0% and 100% labels. The reader will interpret the bar as beginning at 0% and ending at 100% from the labeling and title.

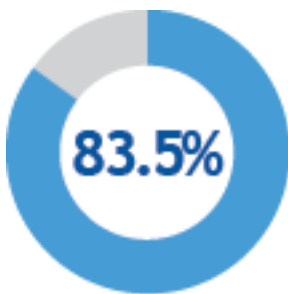
Color

Use UNC Blue [RGB: 75, 156, 211] for the percent complete segment and gray for the complement. Other colors may be used thematically (for example, a specific outcome is consistently in a specific color).

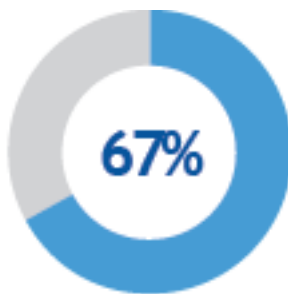
Example 20 - Donut Chart

Donut Chart

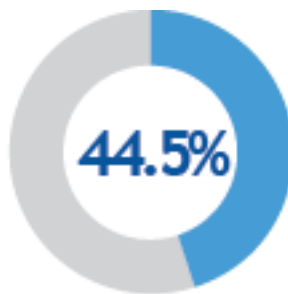
Legend Title: ■ Label ■ Label



Goal 1



Goal 2



Goal 3

Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Donut charts are used to show progress towards a goal as percent complete. Small multiples are an effective use of donut charts. If the primary outcome of interest is the proportionality of more than two measures, a stacked bar chart, treemap, or pie chart is a better choice.

Design Best Practices

- Place the “percent complete” label inside the donut using a formatting approach similar to a card visualization. This approach will use the visual space efficiently.

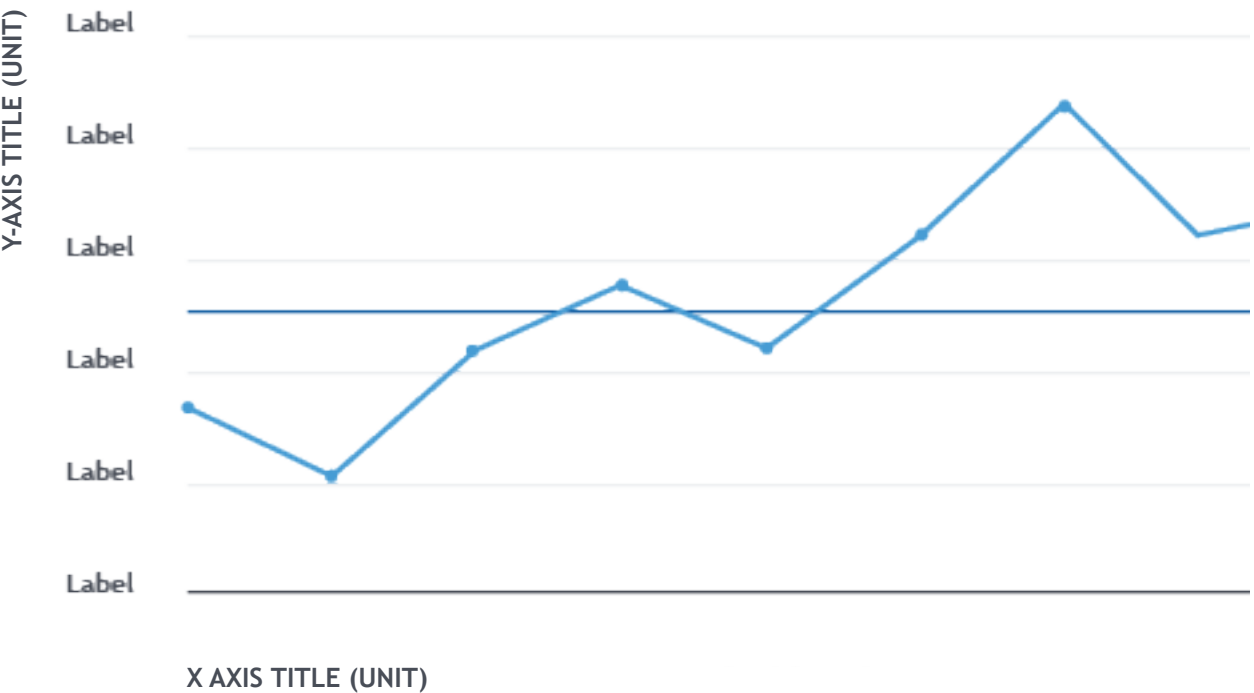
Color

Use a single primary palette color (for example UNC Blue [RGB: 75, 156, 211] for the percent progress/complete and gray for the complement). Other colors may be used thematically (for example, a specific outcome is consistently in a specific color).

Example 21 - Line Chart With Goal Line

Line Chart With Goal Line

Legend Title: ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



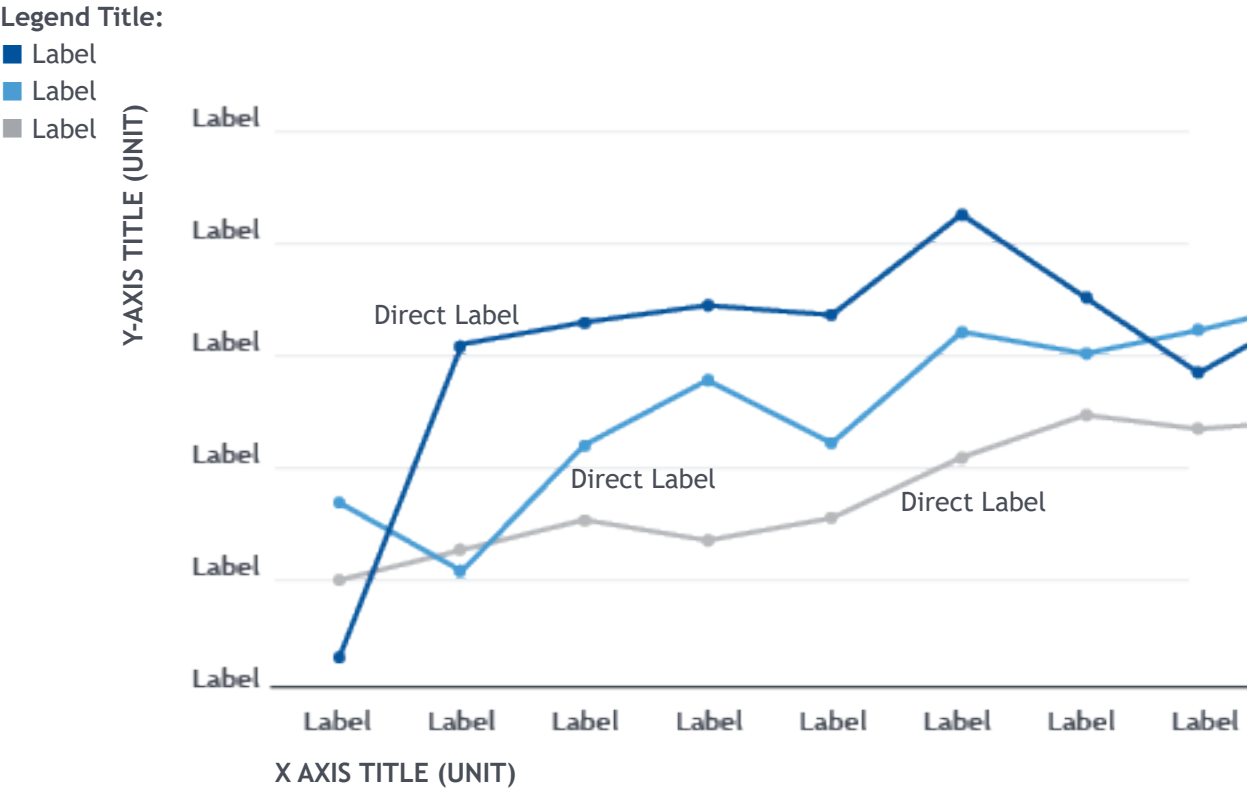
A line chart with a goal line shows the progression towards a goal over time. Two lines can be added to a line chart to show if a process or project is performing below expectations or exceeding a specified goal for the indicator.

Design Best Practices

- Do not use a line chart with goal line to track multiple measures. This introduces ambiguity about which goals are assigned to which measure. Only use line charts with goal lines when tracking a single measure.
- Do not apply smoothing to lines. Interpolating lines in a line chart distorts the data and can lead users to misinterpret the visual.
- Equally space all axis intervals. Place x-axis labels at intervals that make sense for the outcome measure, (e.g., weekly or monthly), even if the data have a more granular level of detail. X-axis labels should be horizontal to maximize readability.
- Clearly label the start and end points of your y-axis and include the zero in the y-axis. When tracking non-negative measures, start the y-axis at zero.

Example 22 - Line Chart

Line Chart



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Line charts are an excellent choice to use for time series data to discern trends and patterns. Line charts are used to show trends over time of continuous measures, or to compare trends across multiple measures. If only a single measure is the outcome of interest, a column chart may be a better visual. If there are too many lines or the lines overlap in a manner that prevents them from being differentiated, consider using small multiples of the line chart.

Design Best Practices

- Do not create line charts with more than five lines unless the values have little overlap and lines can be clearly differentiated. Adding too many lines to a line chart clutters the data and makes the visual difficult to interpret, resulting in a “spaghetti chart.”
- Do not apply smoothing or averaging as you develop the line from your data. Smoothing and averaging interpolates the data and can lead users to misinterpret the visual. Each line should connect data point to data point.
- Equally space all axis intervals. Place x-axis labels at points that make sense for your data, (e.g., weekly or monthly), even if the data have a more granular level of detail.
- Clearly label the start and end points of your y-axis and include the zero in the y-axis. When tracking non-negative measures, start the y-axis at zero.
- Use markers to distinguish the different measures displayed in your chart. This adds another layer of distinction between the different measures and is easy to interpret for colorblind readers.

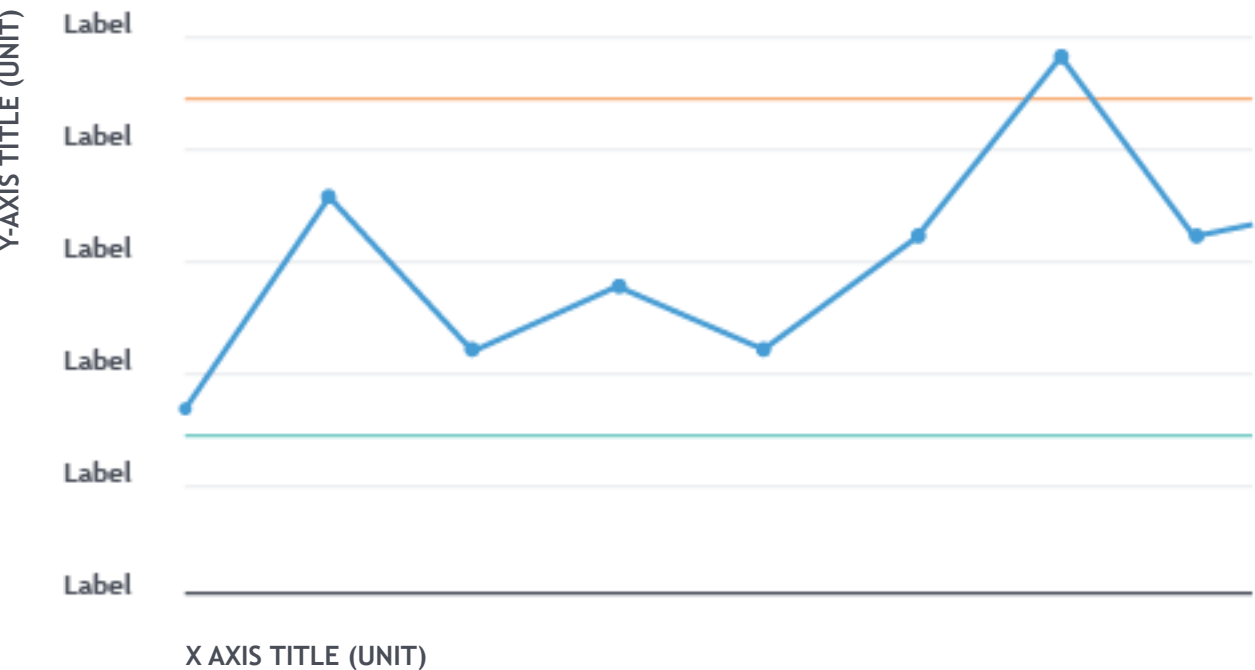
Axis and Gridlines

Do not use dual y-axes with differing scales, as this makes line charts confusing and difficult to interpret. Axis intervals should be equally spaced and should start at zero. If many lines are needed in a line chart, consider using small multiples to avoid overlapping data that can lead to a “spaghetti chart.”

Example 23 - Line Chart With Control Lines

Line Chart With Control Lines

Legend Title: ■ Label ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Control charts are a useful visualization to track trends in time series data and identify when something abnormal is causing a spike or valley in the values of some continuous measure. This is accomplished by displaying two lines, called upper and lower control limits, which create a band that shows where “normal” data should fall in the chart. When the trend line of the chart is above or below these lines it indicates that the process generating the data is “out of control”—in other words, that there is a special cause creating the variance in the data. Control charts are used in a variety of contexts to identify concerning spikes in data—notably in tracking infections in hospitals or production numbers in factories.

Design Best Practices

- Do not use control charts to track multiple measures. Sensible upper and lower control limits can only be created for a single measure at a time.
- Do not apply smoothing to trend lines. Interpolating lines distorts the data and can lead users to misinterpret the visual.
- Equally space all axis intervals. Place x-axis labels at points that make sense for your data, (e.g., weekly or monthly), even if the data have a more granular level of detail.
- Clearly label the start and end points of your y-axis and include the zero in the y-axis. When tracking non-negative measures, start the y-axis at zero.
- If the lower control limit for your data is negative, but the value of the measure is always non-negative, place the lower control limit at zero.

Color

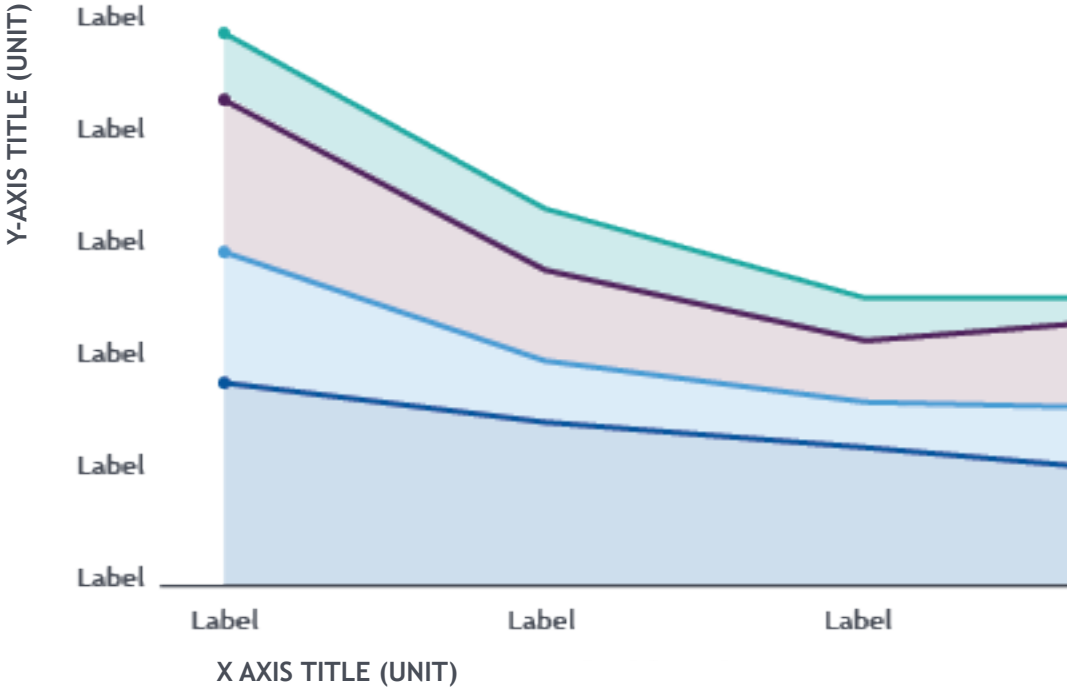
Often in a control chart, spikes above or below the control limits have positive or negative interpretations (e.g., when tracking infections over time, a large positive spike is a problem while a large negative spike is good). If this is the case, use the indicator colors in the Data Visualization Colors section appropriately according to the situation.

Example 24 - Area Chart

Area Chart

Legend Title:

- Label
- Label
- Label
- Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Area charts are a visual that shows how multiple different continuous measures contribute to a total value over time. They are particularly useful for showing cumulative data. A natural use case for an area chart is showing the total number of tests administered up to a particular time, subdivided by the race or age group of those receiving the tests.

Design Best Practices

- Place the largest contributing value to the area chart at the bottom of the chart. This should be done based on what the largest value is at the beginning of the time period shown in the chart.
- Y-axes should always start at zero and axis intervals should be equally spaced. Place x-axis labels at points that make sense for your data, (e.g., weekly or monthly), even if the data have a more granular level of detail.

Color

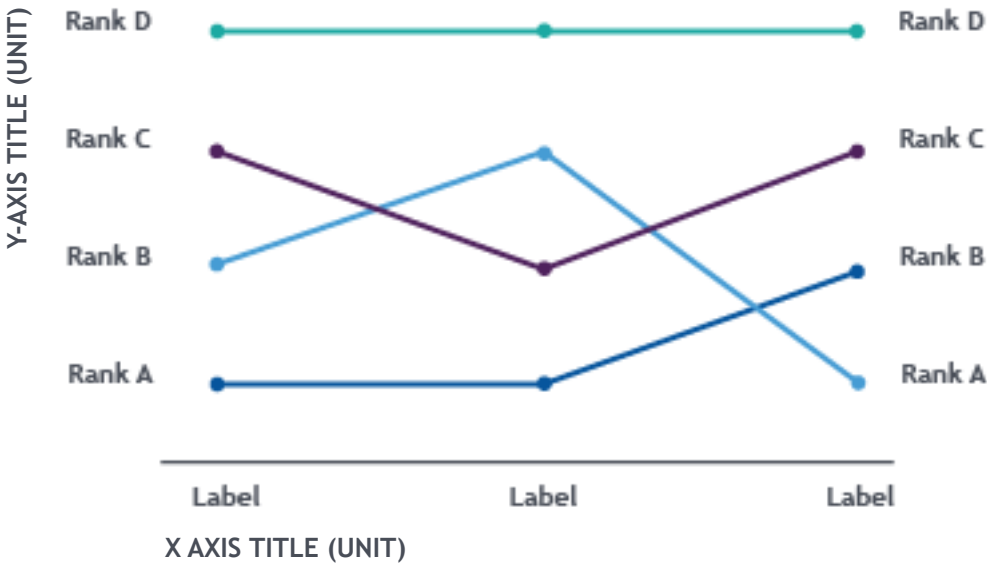
Use the full color palette given in the Data Visualization Colors section to distinguish between the different contributing categories.

Example 25 - Bump Chart

Bump Chart

Legend Title:

- Label
- Label
- Label
- Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Bump charts are used to track the change in rankings of an outcome between categories over time. An example includes tracking which COVID-19 at-home test is being used most (and least) frequently over time. Importantly, bump charts only display the ranking order and do not discern the exact value difference. Because the y-axis represents the rank order and not the outcome value, it avoids line cluttering. However, if exact values are important, consider using a line chart, or small multiples of line charts.

Design Best Practices

- Bump charts lack the detail of other visualizations, because they only show the relative rankings of categories without showing the value of the underlying measure the ranking represents. This limitation can be avoided by showing the ranking measure in the tooltip of the visualization.

Color

Use color to differentiate between categories or to emphasize the data that are most important to the reader. When tracking rankings of projects without an emphasis on a specific project or projects, for example, use the colors from the full color palette. To emphasize a specific category or categories, use the full color palette for these and gray for the remaining ones.

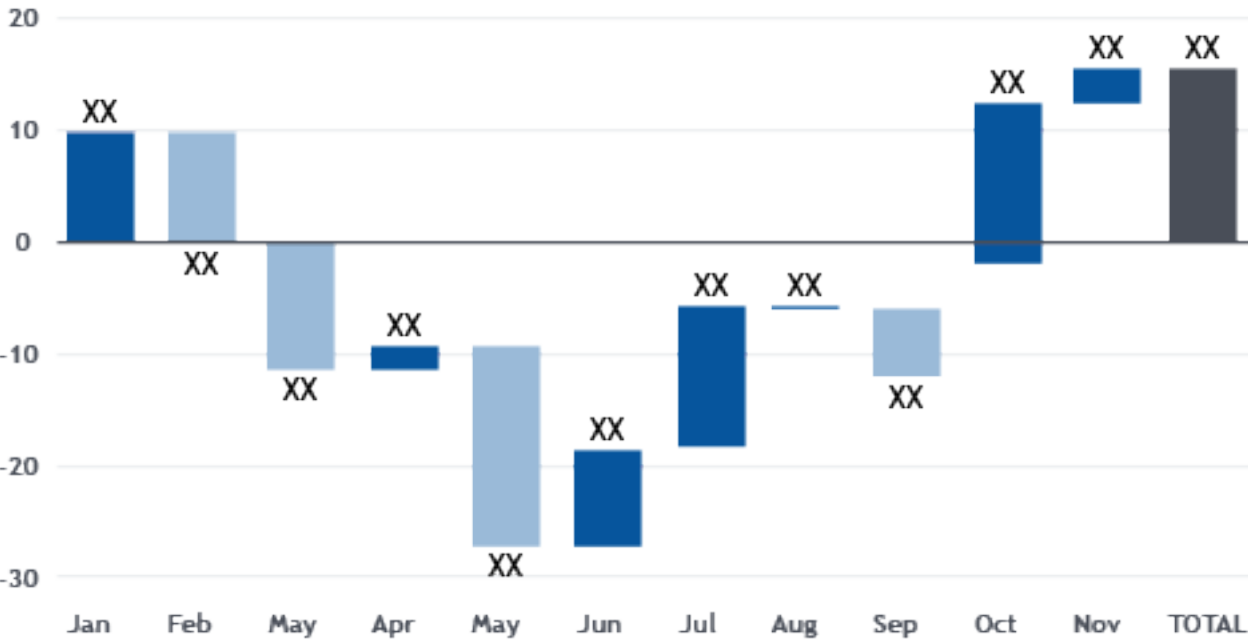
Axis and Gridlines

Clearly display the ranking order and category label in the y-axis. Also include the rank and category label as a dual y-axis on the right side.

Example 26 - Waterfall Chart

Waterfall Chart

Legend Title: ■ Label ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.

Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Waterfall charts are useful for examining how a single measure (e.g., total budget) changes from a starting value to an ending value as a result of increases or decreases of the value over time. An example includes tracking the net number of additional hospital beds occupied or vacated at the end of each day.

Design Best Practices

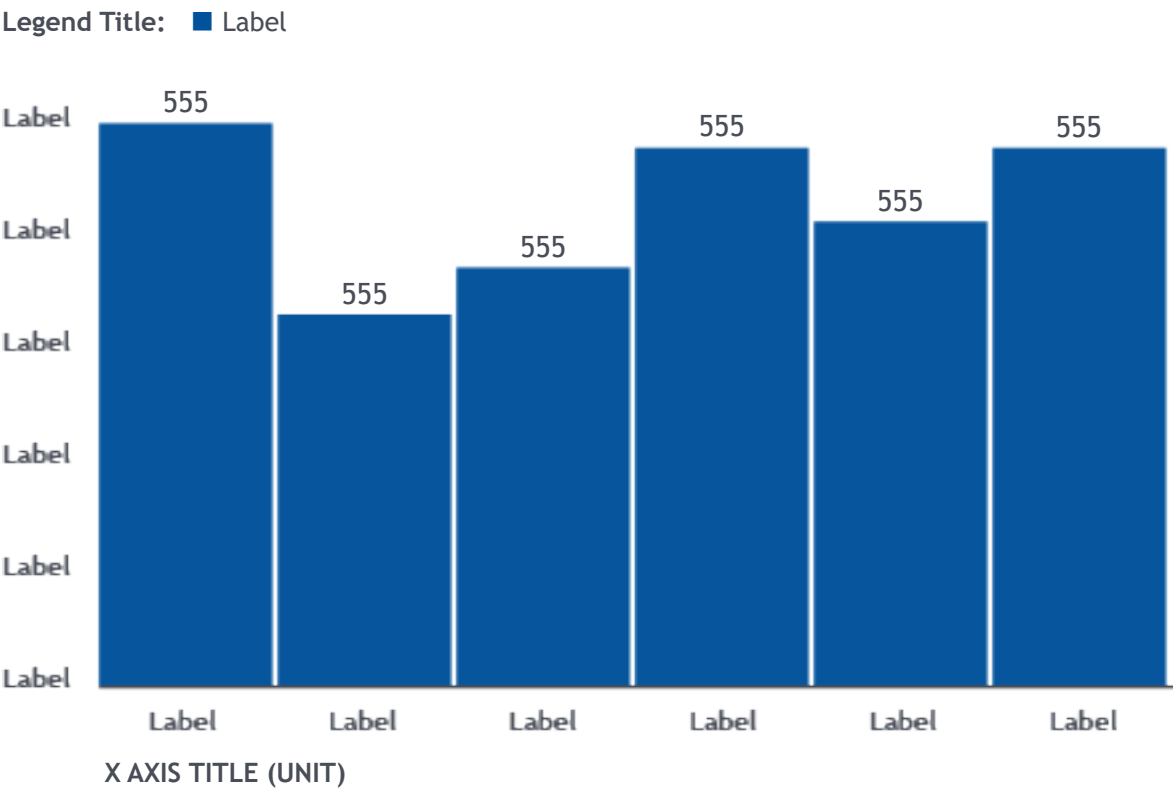
- Make bars in a waterfall chart rectangular to clearly show where the bars start and end.
- Do not use 3D effects in waterfall charts for the same reason.
- Place a horizontal zero line on the chart to ground the reader and provide context to the additions and subtractions.
- Place data labels outside the top of the bars for additions and the bottom of the columns for subtractions.

Axis and Gridlines

Use the y-axis and gridlines for the reference of each period's total. The direct labels display the relative change (net increase or decrease) between each period. Use dark gray for the total column.

Example 27 - Bar Histogram

Bar Histogram



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Bar histograms are used to visualize the distribution of one measure against bins of a related measure, such as displaying the frequencies of employees at a company within binned salary ranges. If bins of multiple measures need to be compared against a single measure, stacked polygonal histograms or violin plots are a better choice.

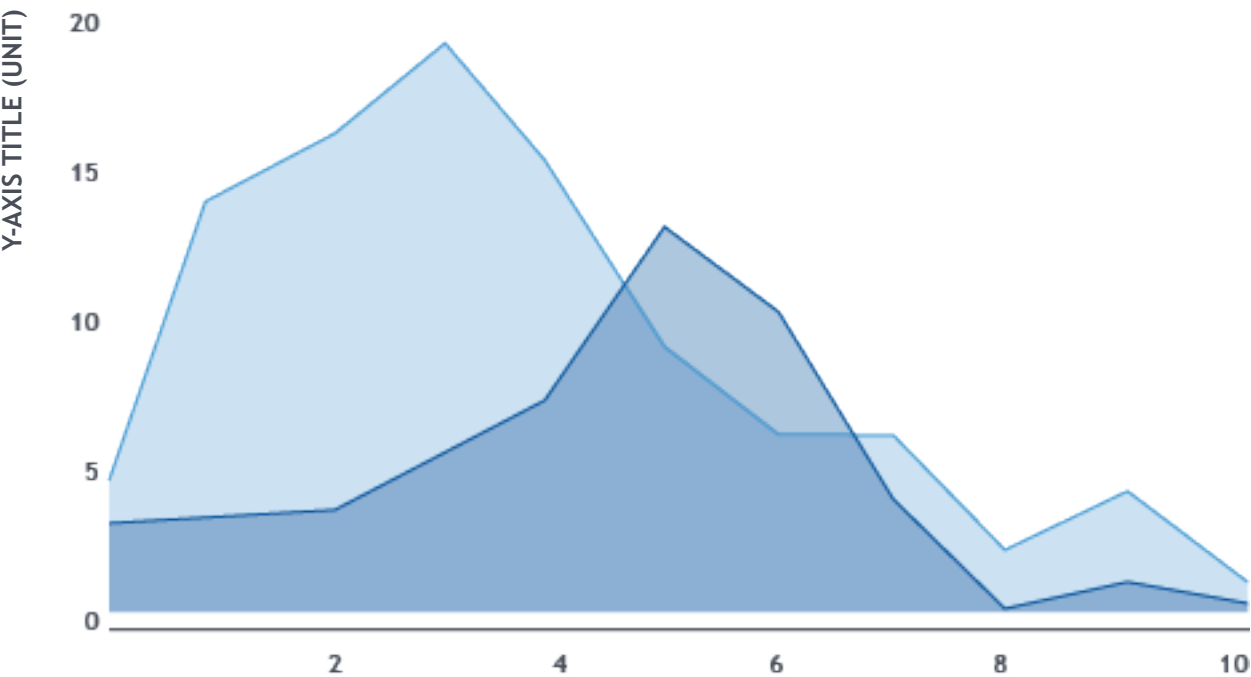
Design Best Practices

- Reduce ambiguity about where the “top” of the bar is by avoiding the use of 3D effects.
- Start the y-axes at zero, so that the reader can easily compare the heights of the bars to one another to get a true sense of the value differences. Truncating the start of the axis can create deceptively large differences across bars even when the differences are small.
- Make the bins equally sized and do not omit bars with no data as this can be deceiving. Choose the number of bins and their size based on the key messages the visualization is meant to convey.
- Place direct labels outside the top of the bars.

Example 28 - Frequency Polygon

Frequency Polygon

Legend Title: ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Frequency polygons are used to understand the shape of a variable’s distribution or cumulative distribution. The distribution of two or three variables can be compared by overlaying their frequency polygons in one graph. If there are more than three distributions, consider using a violin plot.

Design Best Practices

- Start y-axes at zero.
- Use equally sized bins. Choose the number of bins and their size to create a meaningful summary of the distribution. Using bins that are too large or too small may fail to show the variation in frequency of the data.

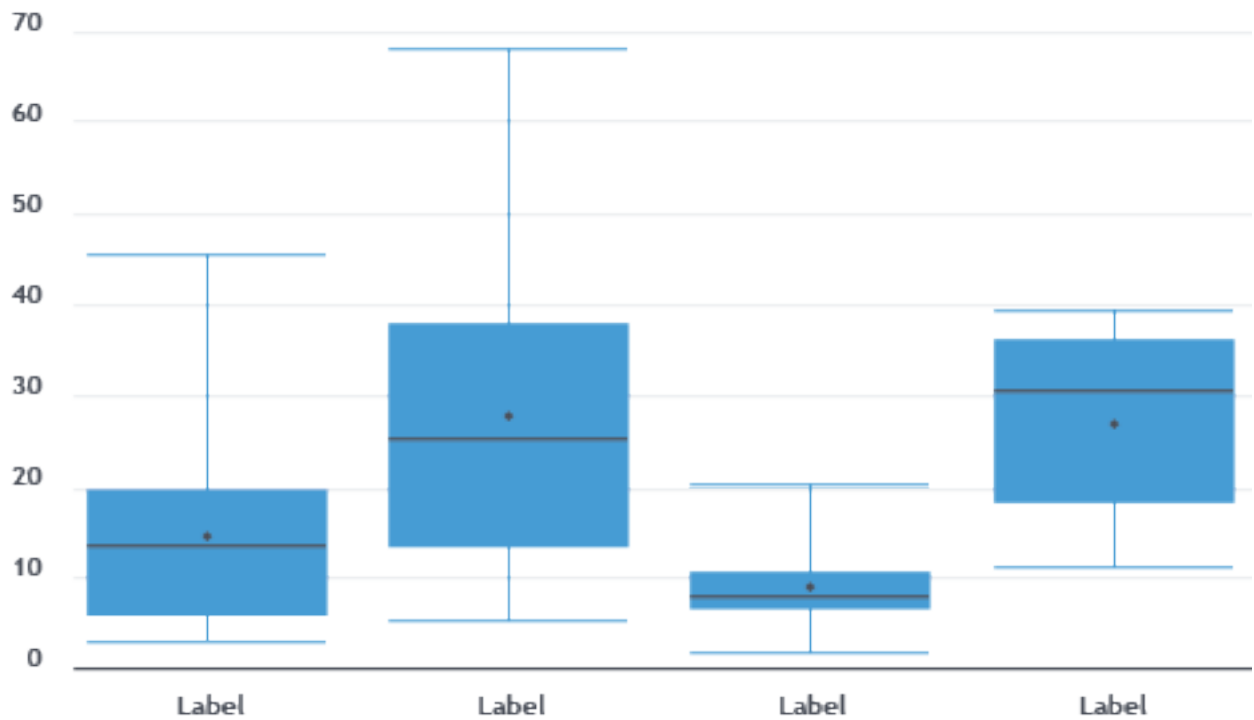
Color

If comparing the distribution of two different measures, use different colors to distinguish them. Fill in the area underneath the lines representing frequencies with the same color as the frequency lines. When overlaying distributions apply 20% transparency to the fill so that the full extent of each line is visible to the viewer.

Example 29 - Box Plot

Box Plot

Legend Title: Label Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Box plots show summary statistics on the distribution of a single measure over time or between nominal groups. Use box plots to communicate means, medians, interquartile ranges, and spreads of distributions.

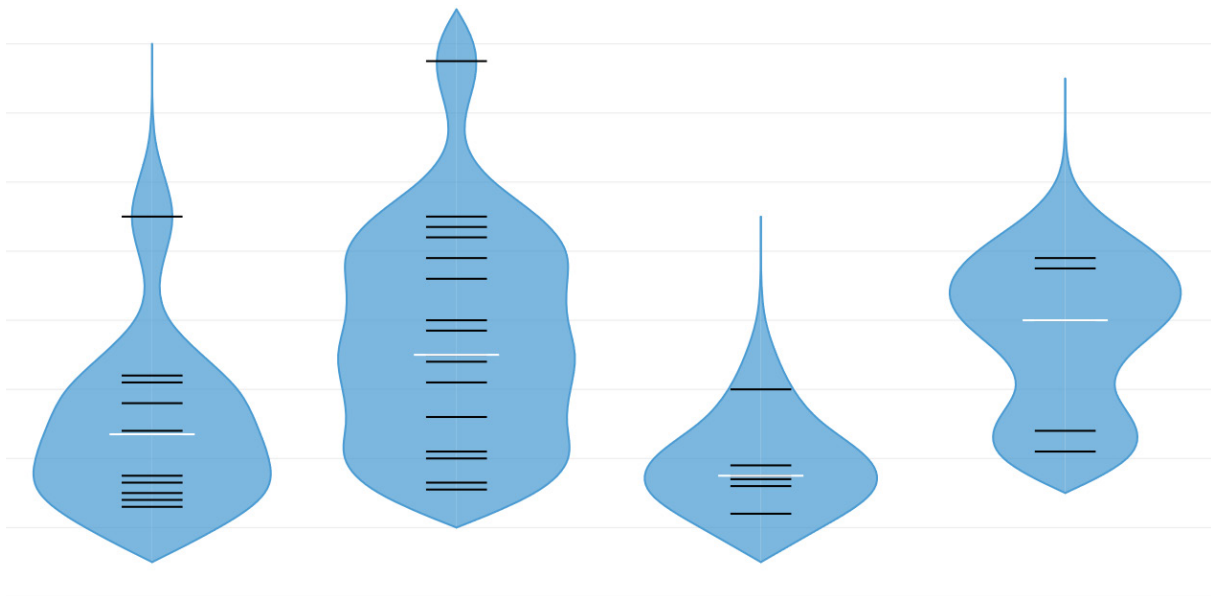
Design Best Practices

- Use box plots for distributions that are unimodal or when only the summary statistics of a distribution are of interest. Many different distributions can generate the same box plots, and they do not show the shape of the distribution. If the shape of the distribution is an outcome of interest, use a violin plot instead.
- Order x-axis categories intentionally. If the x-axis is ordinal, use the natural ordering. If the x-axis categories are nominal, consider ordering the box plots by their means or medians to show this ranking.

Example 30 - Violin Plot

Violin Plot

Legend Title: ■ Label ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Violin plots show change in distribution over time, or between different groups or projects. If you wish to display how a distribution changes from month to month, for example, a violin plot will reduce the confusion that might arise from having several stacked polygon histograms.

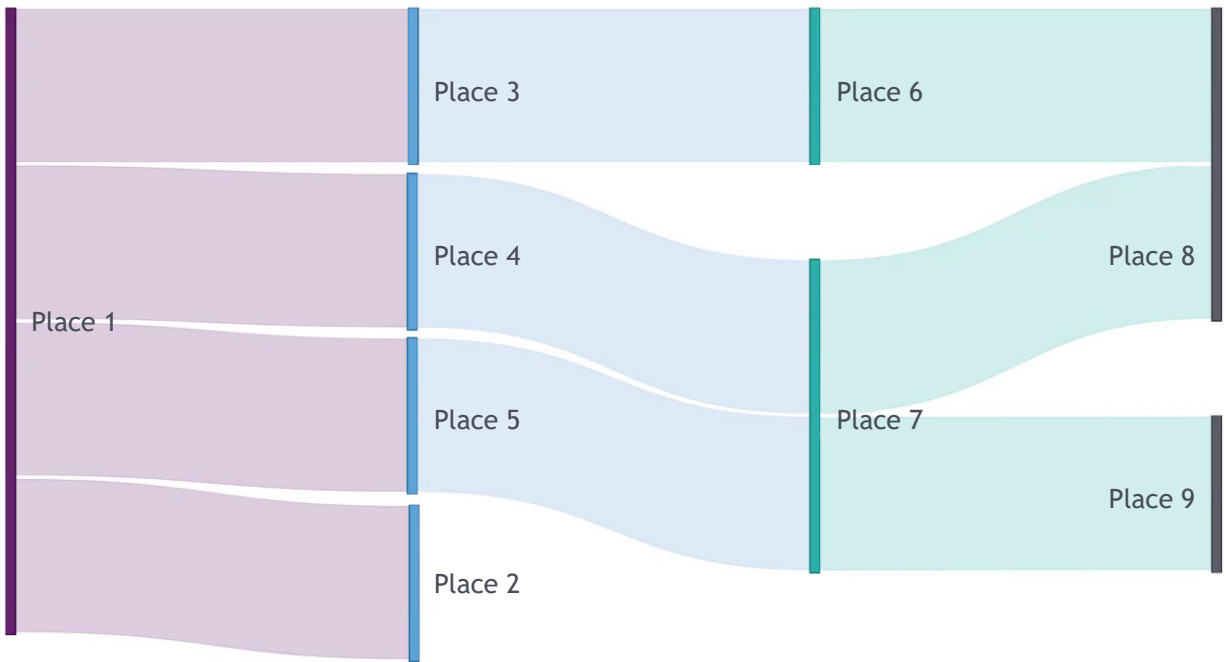
Design Best Practices

- Use violin plots only when the underlying dataset has many points to ensure this estimation reflects the underlying distribution accurately. Violin plots display a smoothed or interpolated distribution that is approximated based on the dataset. Because of this, the distribution visualized is only an estimation of the underlying distribution function, which may not capture the true distribution of the data.
- Be intentional about the category order when constructing the visual. If comparing changes in distribution over time, use the natural time series order for the x-axis. If comparisons in distribution are being made across nominal groups, consider ordering the distributions by their mean values to emphasize the ranking.
- Use a white bar to represent the mean or median of each distribution.

Example 31 - Sankey Diagram

Sankey Diagram

Legend Title: ■ Label ■ Label ■ Label ■ Label ■ Label ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Sankey diagrams are useful for visualizing how resources are distributed over time or within a system. They can be used to visualize data such as budget allocation or user behavior on websites. Sankey diagrams emphasize where resources are distributed rather than how much of a resource is being distributed.

Design Best Practices

- Avoid overlapping flows in your Sankey diagram.
- Color linkages between nodes using the same color as the source node.

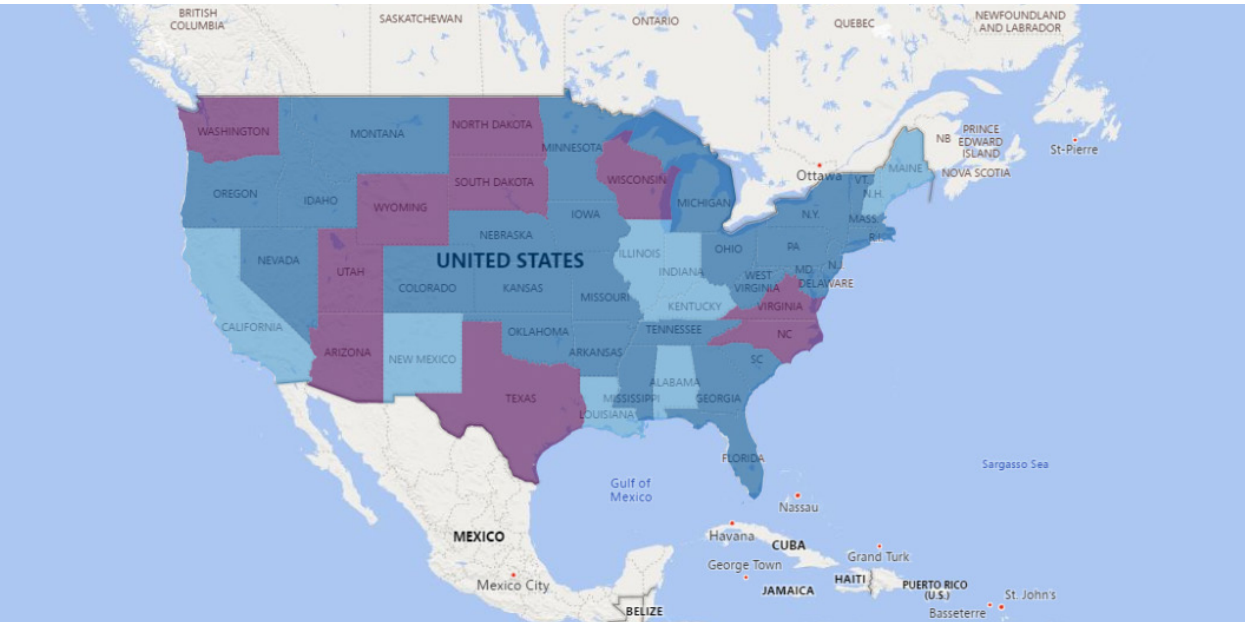
Color

Use the primary colors in the color palette order as needed.

Example 32 - Choropleth Map

Choropleth Map

Legend Title: ■ Label ■ Label ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.

Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Choropleth maps can be used to compare the values of both continuous and categorical measures across counties, districts, and regions. Natural use cases include showing the regions that a certain project is active in, or showing the number of projects operating in a region. If state-level values are the primary outcome of interest, a better choice is a hex map.

Color

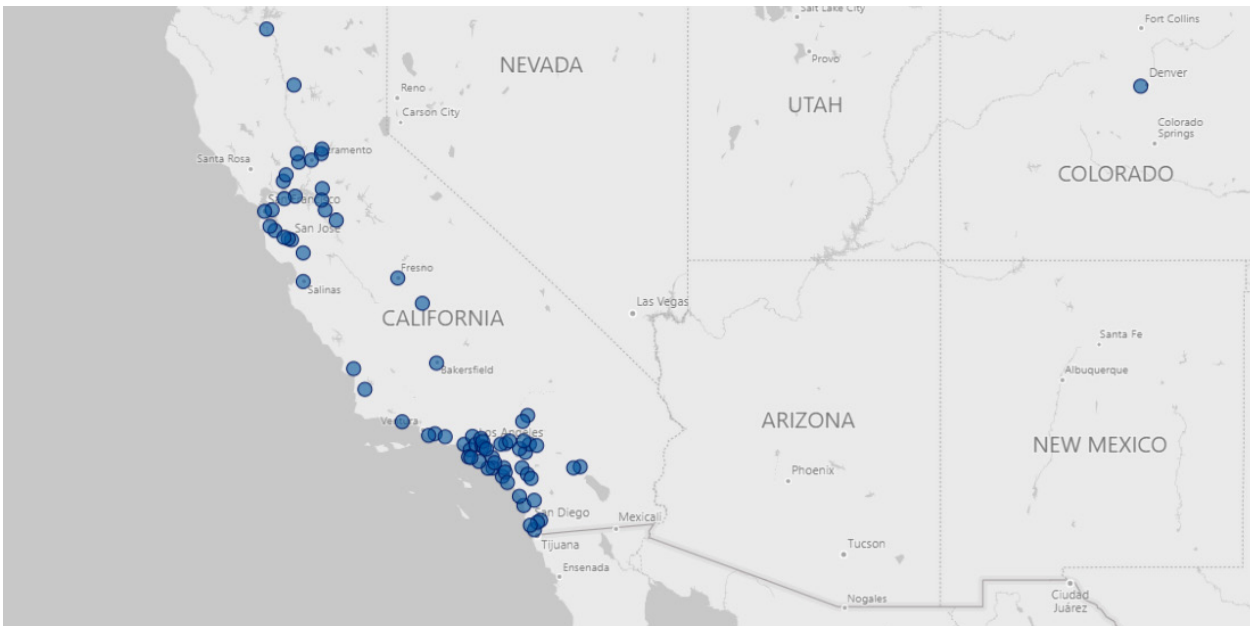
As with all data visualizations, use color intentionally. If the color is meant to represent a category (e.g., whether a project operates in a region), multiple distinct colors should be used for the data colors. If the color represents the value of a continuous variable (e.g., Social Vulnerability Index), a gradient of a single color should be used. As a best practice, it is recommended that continuous measures are binned into meaningful category value ranges. When using a sequential monochromatic (single color) scale, at most five shades of a color are used, because more shades cannot be discerned by most individuals. For additional categories, use a divergent (Eggplant [RGB: 81, 12, 93] to Duke Blue [RGB: 0, 83, 155]) or bivariate color range of contrasting colors for up to nine categories.

Consider the relative size of each shape within your Choropleth map. When important regions or states are not visible due to their smaller relative size, consider switching to a HexTile map which will give equal size and visual dimension to each geographic subgroup presented.

Example 33 - Point Map

Point Map

Legend Title: ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



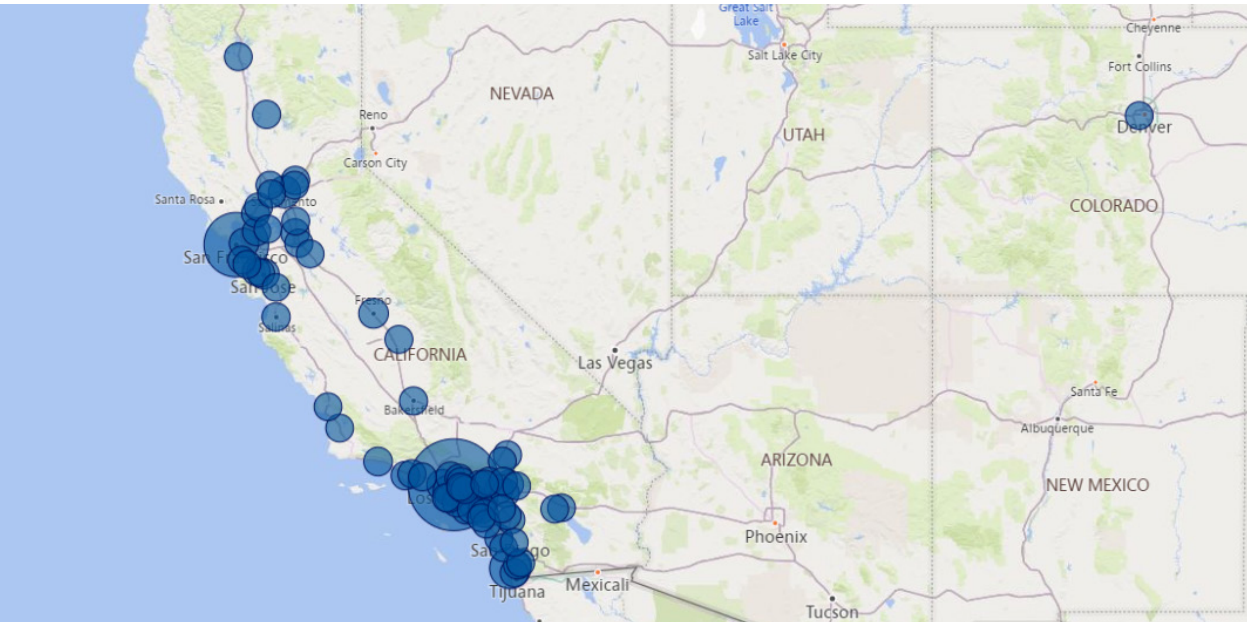
Point maps are used when the data of interest are the location of specific sites. An appropriate use of a point map would be to show the locations of all project-related testing sites within a state.

Color
Use color to highlight points of interest on your map. High or low performers in COVID-19 testing can be highlighted using the indicator colors given in the Data Visualization Colors section. Colors can also be used to show qualitative differences in testing sites, like type of test administered.

Example 34 - Bubble Map

Bubble Map

Legend Title: ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Bubble maps are useful for data in which there are specific geographic points of interest (e.g., testing sites), as well as a measure associated with the points (e.g., number of tests administered). Using bubble maps allows the designer to put more information into a single visualization than just a point map, similar to the relationship between scatter plots and bubble charts.

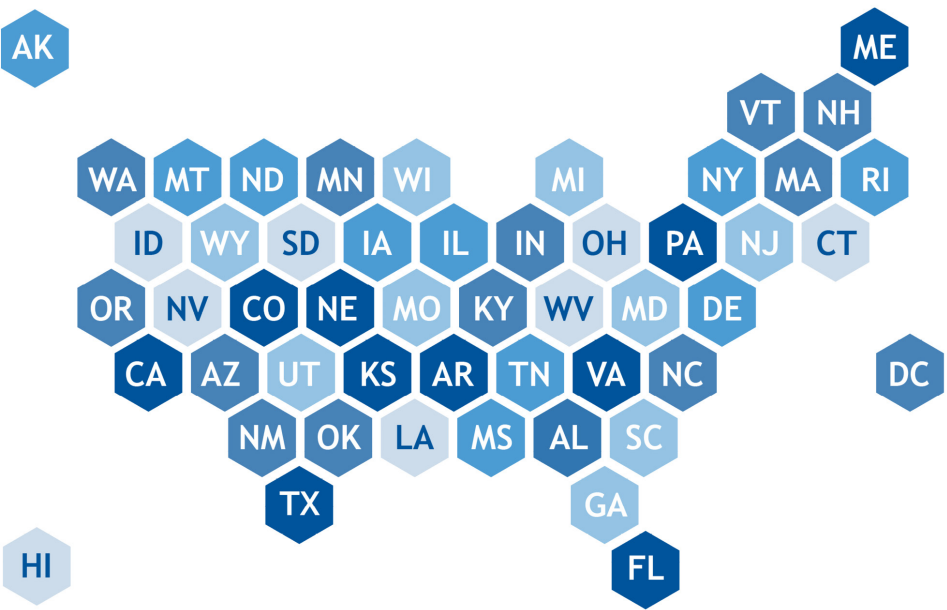
Size
Consider how visible each bubble will appear on the map. Generally, bubble maps use a direct scale to the count of the item being represented. However, due to bunching of bubbles, or due to the a large range between the minimum and maximum values represented (e.g., 5 clinics vs. 50,000 clinics), you may choose to categorize your bubble sizes to 4-5 bubble sizes. Each size would then correspond to a range of values which can be defined in the legend. Cut-points could be determined based on quartile or quintile ranges or by meaningful administrative values or thresholds that are useful for program planning or policy making.

Color
As with all data visualizations, use color intentionally. If the color is meant to represent a category (e.g., whether a project operates in a region), multiple distinct colors should be used for the data colors. If the color represents the value of a continuous variable (e.g., Social Vulnerability Index), a gradient of a single color should be used. As a best practice, it is recommended that continuous measures are binned into meaningful category value ranges. When using a sequential monochromatic (single color) scale, at most five shades of a color are used, because more shades cannot be discerned by most individuals. For additional categories, use a divergent or bivariate color range of contrasting colors for up to nine categories.

Example 35 - Hex and Tile Maps

Hex and Tile Maps

Legend Title: ■ Label ■ Label ■ Label ■ Label ■ Label ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



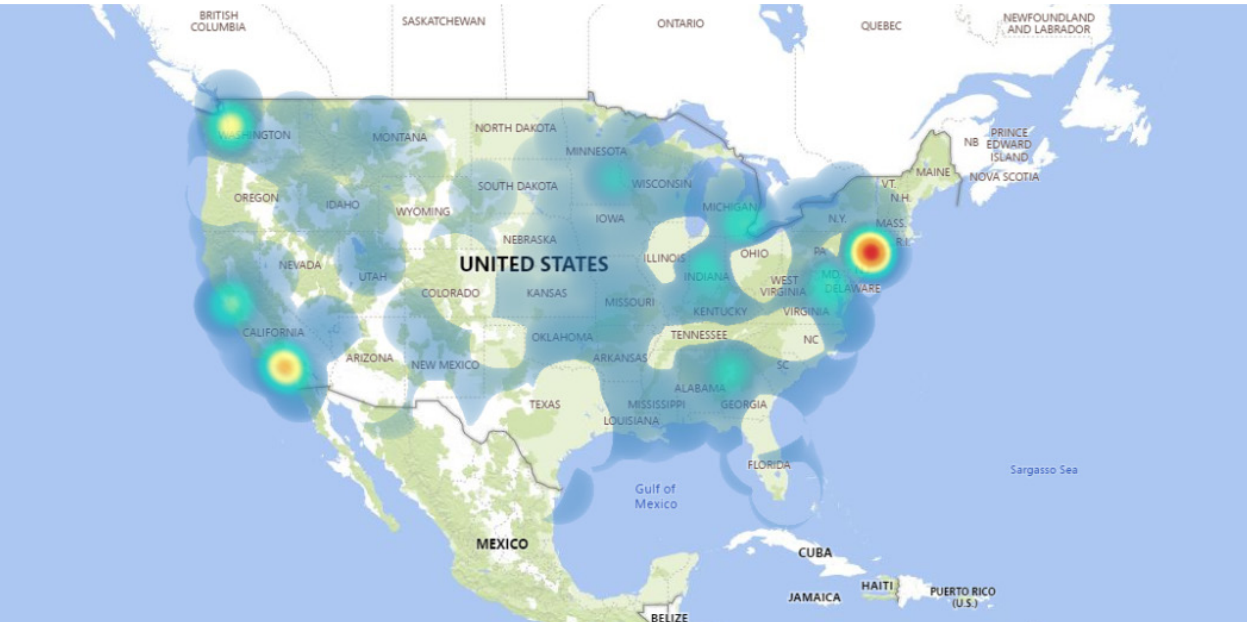
For state-level comparisons, hex and tile maps provide a way of visualizing data that avoids giving an outsized portion of a map visualization to large states and a diminutive portion to small states. Hex maps give equal visual weight to all states, making it easier to see the eastern states, which are cluttered together in the typical general reference maps of the U.S. Examples of hex map uses include visualizing which states have passed a policy, how many programs participate in a state, or percent vaccination by state.

Color
As with all data visualizations, use color intentionally. If the color is meant to represent a category (e.g., whether a project operates in a region), multiple distinct colors should be used for the data colors. If the color represents the value of a continuous variable (e.g., Social Vulnerability Index), a gradient of a single color should be used. As a best practice, it is recommended that continuous measures are binned into meaningful category value ranges. When using a sequential monochromatic (single color) scale, at most five shades of a color are used, because more shades cannot be discerned by most individuals. For additional categories, use a divergent or bivariate color range of contrasting colors for up to nine categories.

Example 36 - Heat Map

Heat Map

Legend Title: ■ Label ■ Label ■ Label ■ Label ■ Label



Source: Font is 9 points on 11 point line spacing. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.



Heat maps can be used to track continuous variables at an extremely granular continuous variables in a geographic space at an extremely granular level. Appropriate uses of heat maps include tracking temperature or pollution levels or smoothed density of point data (e.g., average number of traffic accidents within 2 miles of a given location). If your data are at the ZIP code, county, or state level a use a choropleth or hex map instead. Only use heat maps when tracking measures that are truly continuous across geography.

- Color*
- Use a continuous divergent gradient based on the Duke Blue [RGB: 0, 83, 155] (low density) to Orange [RGB: 244, 126, 40] (high density):
- Level 5, Duke Blue [RGB: 0, 83, 155],
 - Level 4, CCPH Tint 2 [RGB: 114,203,199],
 - Level 3, Dark Gray Tint 5 [RGB: 236, 237, 238],
 - Level 2, Marigold [RGB: 223, 197, 0],
 - Level 1, Orange [RGB: 244, 126, 40].

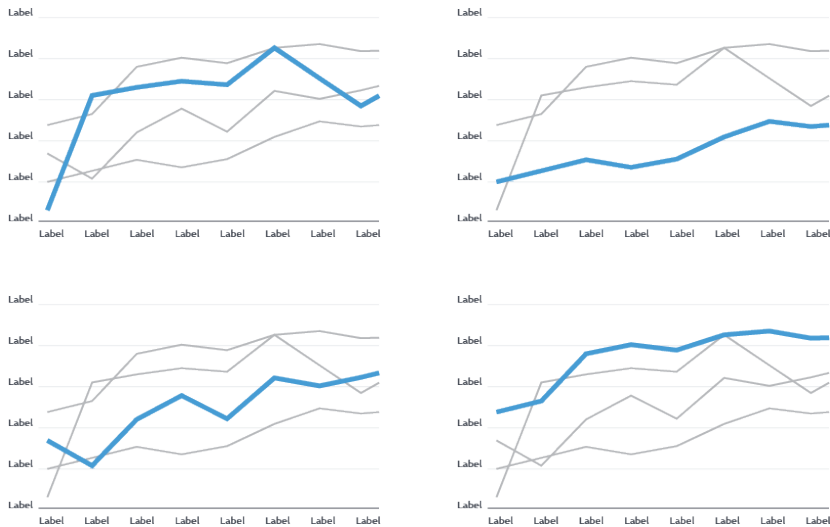
4. Multi-Chart Visualizations/Combining Visualizations

This section describes three types of multi-chart visualization formats that you might choose to use in your work.

Small Multiples/Faceted Plots

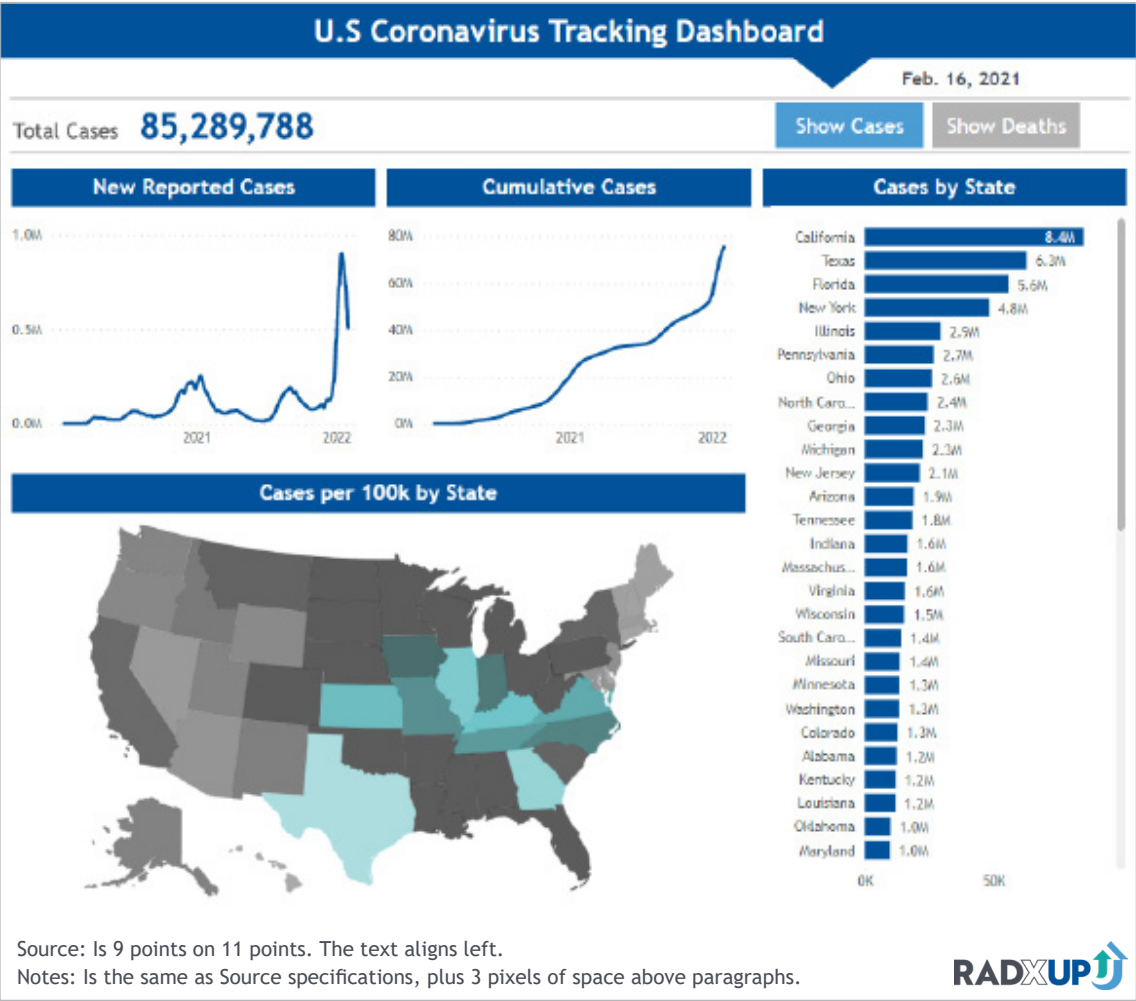


One way to present complex charts for better comprehension is to display your data in small multiples, also known as facet plots. Small multiples can be used to show complex or regional data that cannot be interpreted easily when placed in a single visualization. They are typically grids or lines of the same visualization that display different data in each chart. For example, vaccination rates over time for eight different cities, or trends by ethnicity over time for eight or more hospitals. In these examples, you might repeat the same chart eight times, with each chart displaying data from a different city or hospital. Small multiples use the same formatting for each visualization in the line or grid of charts and start axes at the same start and end points to ease interpretation and comparison across charts.



Dashboards

A dashboard weaves a collection of single data point displays, charts, graphics, maps, and tables together to tell a broader story and provide users access to a collection of related graphics in one view. The goal of a dashboard is to develop a presentation solution that allows users to see and interpret multiple data points related to an issue or use case in a simple format. In addition, the data populating the dashboard are often linked by key variables (e.g., hospital name, city, state) and over time (e.g., year, month, quarter), so that the presentation in the dashboard can be limited to relevant geographic areas and time-points by the user. Often dashboards will include both static indicators of measure status (e.g., data cards) as well as charts describing trends or progress towards a goal (e.g., line graphs, waffle plots) and maps (e.g., choropleth maps) showing the relationship between outcomes or needs across a geographic area. Some dashboards allow further “drill-downs” of the data where



Source: Is 9 points on 11 points. The text aligns left.
Notes: Is the same as Source specifications, plus 3 pixels of space above paragraphs.

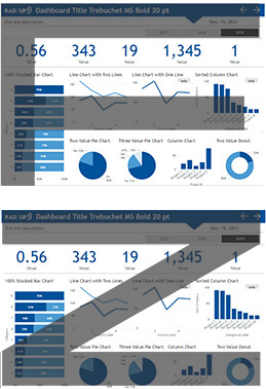
the user can click on a subgroup presented within a chart (e.g., age group 25-44), which will reorganize the data display to just show data and outcomes for a particular subpopulation of interest. The goal is to simplify the process of accessing and combining multiple related data points to improve program planning, user understanding of complex issues, and monitoring of outcomes.

Visualizations presented in the dashboard can provide broad context around an issue as well as more detailed charts. Combining the two approaches can efficiently answer particular questions or scenarios that you often experience in your work.

Planning With Wire Frames

Do not feel like you need to jump right into your visualization platform as a first step. Use PowerPoint graphics or other whiteboarding software to draft sketches of the content you could present and anticipate will be meaningful. Once you have a few options to consider, gather 2-5 individuals who will likely use the dashboard and ask them for their feedback on the mock-up. It can also be helpful to include data analysts and senior researchers in these discussions, as they may be aware of additional datasets and options for linking and filtering data that should be considered early in the design process. They may also have feedback on any issues with data propriety and data structure for making appropriate links across datasets to support the anticipated visuals.

Dashboard Layout. Most audiences will read visualizations from left to right and then top to bottom. A good rule for constructing compelling dashboards is to design them in an “F” or “Z” shape. The most important visualization or highlight should lie at the top left of the page, and the story you want to tell with your data should move in an “F” or “Z” pattern throughout the rest of the page. By following this principle, you can ensure that the dashboard has a clear visual hierarchy that doesn’t overwhelm the audience.



Scale of the Dashboard:

- Deciding on a fixed size for your dashboard will help you to manage space more efficiently as you populate it with visualizations. For example, if a dashboard will be accessed on a browser it should be 1000 pixels wide by 750 pixels tall to ensure a wide range of monitors and browsers will be able to view it in its entirety.

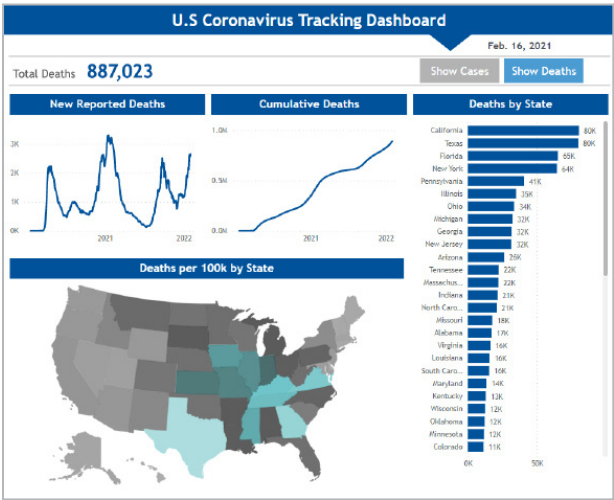
Data Management Considerations

Dynamic dashboards often provide filters to limit the data for a full dashboard page, or to select subgroups of the data, quickly “drilling down” into the story or context for subpopulations of interest (e.g., for a particular race/ethnicity, state). For this reason, you will want to pay close attention to the “key” variables you will use to link your data. This includes making sure all states, ZIP codes, organization identifiers, and data labels are consistent across the data sets you aim to bring together. It can be helpful to start a data dictionary or table in Excel to reference and closely review all data closely before they are added to or updated in the dashboard.

Design Considerations

The dashboard should help you understand and monitor your research and discern differences between groups and changes over time or against established metrics. These considerations will help the dashboard explain your activities to others, and potentially help plan activities in the future. Let’s walk through an example below.

Highlight key statistics that show the status of core metrics in cards along the top of the design—for example, case counts for the county and for a selected region of interest. Graphics that are related or can be compared should be in close proximity on the dashboard (e.g., number of cases and cases per 100,000). Keep in mind that viewers will tend to compare values that are alongside or near each other, so standardizing axes’ lengths and consistently or meaningfully calibrating magnitudes across graphs should be considered.



Use color sparingly in your dashboard to guide the user to key points of interest or takeaways within the included charts and graphics (e.g., use a consistent “accent” color to indicate the average, the category with the greatest prevalence, or the category with the greatest variation across charts).

As you develop your dashboard, collect and maintain a list of the resources and data sources included. Ensure you use tooltips within the dashboard or include a footer with links to a description of the data sources used and any data limitations identified.

Infographics

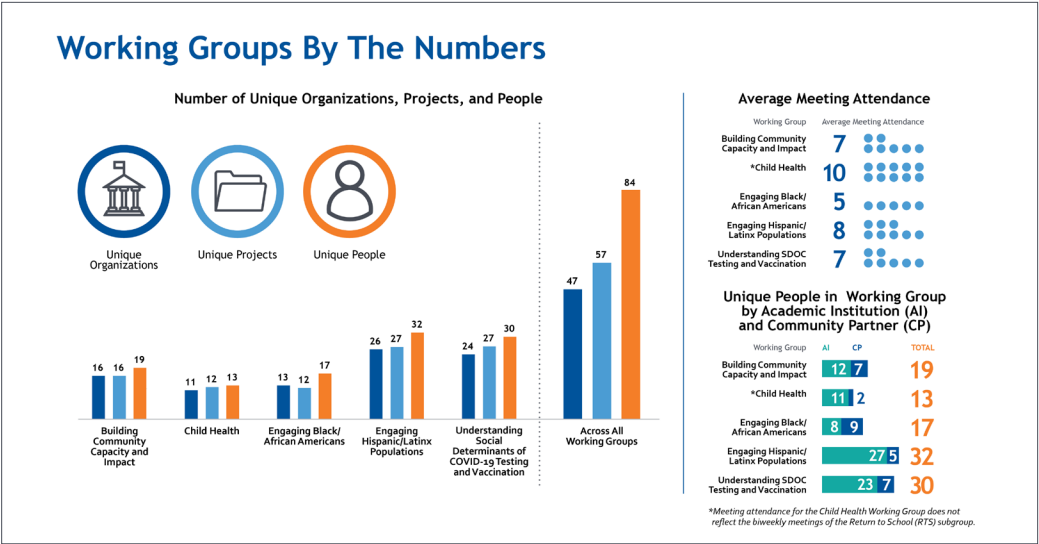
While dashboards prioritize timely data, infographics focus more on the storytelling. Infographics are collections of data visualizations, illustrations, text, and images to tell an easy-to-understand story about a topic. They are useful if you want to simplify complex concepts, make comparisons, summarize long content, or build greater awareness about an issue. Consider the following guidelines when designing an infographic.

Infographic Outline

Create an outline template and think about where and how you want to present different pieces of the information. Focus on the structure of the information you want to present, rather than the detailed design. You can use a grid to arrange different sections. Choose the layout and size of the template based on your planned dissemination strategy and the platform you anticipate using for dissemination. Your infographic could be vertical, horizontal, square, small, or big depending on your audience and communication goals. If you plan to share the infographic on blogs or websites, then vertical layouts are a good choice because readers can easily scroll up and down the infographic on the screen. If you want to print it or share it in your presentation, fit the layout within the size of a piece of paper. For social media, consider the aspect ratio (relative measurement of the width and height) of the particular platform.

Information Organization

Organize the information in a simple way so that your audience won’t get lost. Like essays, good infographics come with a three-part structure of introduction, main body, and conclusion. In the introduction, you have the chance to spark the curiosity of your audience about the topic. Choose a powerful title and a brief paragraph of the text focusing on their pain points to convince them that the infographic is interesting. The main body should communicate the key message. Usually, large data visualizations are placed here to convey the main point of information. To tell a compelling story, you should intentionally order the content using different text formatting styles, particularly headings and bulleted or numbered lists. The conclusion is where you wrap up the message and add any call to action for the reader. Don’t forget to add sources of data to your infographic at the end or in footnotes at the bottom of each chart.



Design Considerations

The two principles to remember when designing infographics are simplicity and hierarchy. You want your audience to understand the message quickly without any distraction. Remember you usually have 5 seconds to capture the attention of your audience and persuade them to go through the whole content. Use simple but engaging visuals and guide them through the story with a hierarchical design. Incorporate different design elements such as size, color, spacing, proximity, and alignment to convey the hierarchy by making some content more prominent than other content. If you want to make specific content appear more prominent, you can make it larger or brighter, create negative space around it, or place it in the center of a group, where there is an equal number of elements on either side. Also, close or similarly aligned elements will have similar priority in the reader’s mind. Use illustrations, images, and icons to eliminate the need for large blocks of text and make the data more memorable. Use colors to draw attention to important data and facts. Add shapes, borders, and lines to position, group, or connect contents.

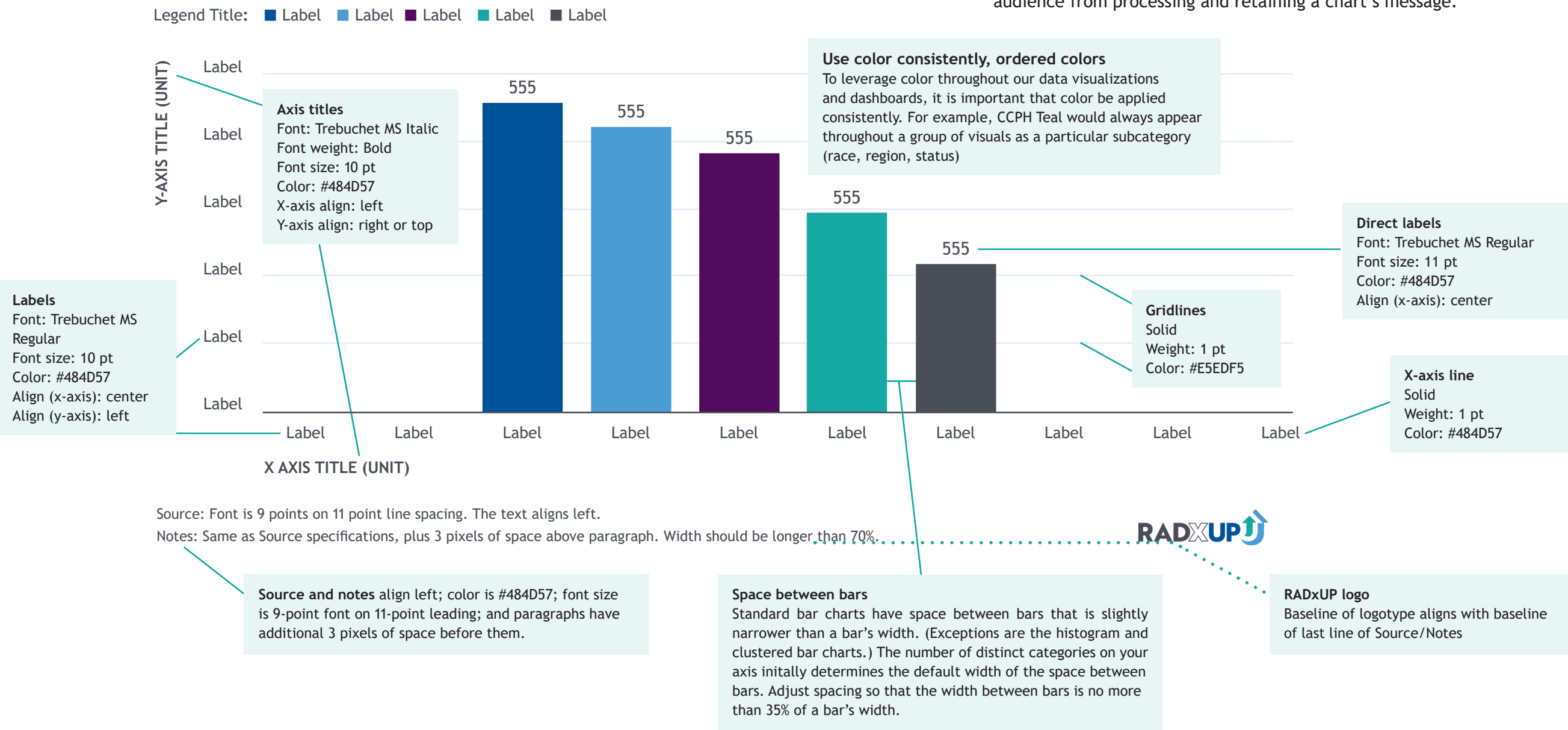
5. Aligning Format, Colors, and Fonts

Format Specifications

This is the Title in Trebuchet MS Regular Font, 18 pt on 20 pt, #484D57

This is a subtitle in sentence case, Trebuchet MS Regular 12 pt font on 20 pt leading (line spacing), #484D57

The diagram below shows elements of a chart and their format specifications. When presenting your data, you may not want to display all the chart elements shown below. It is best to remove chart elements that distract your audience from processing and retaining a chart’s message.



Data Visualization Colors

The top row of the chart below shows RADx-Up (Main) brand colors and is indicated by a solid black border. Each chart entry shows the HEX and RGB formulas for each color. Gradients of

each Main color are provided in rows 2-6 for use in visualizations such as maps. Indicator colors in row 7 are used to indicate Good/Neutral/Bad categories.

Main colors

<div>Duke Blue RGB: 0 83 155 HEX: 00539b</div>	<div>UNC Blue RGB: 75 156 211 HEX: 4b9cd3</div>	<div>Eggplant RGB: 81 12 93 HEX: 510c5d</div>	<div>CCPH Teal RGB: 20 169 162 HEX: 14a9a2</div>	<div>Dark Gray RGB: 71 77 87 HEX: 484d57</div>	<div>Orange RGB: 244 126 40 HEX: f47e28</div>
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Tints/gradients of

<div>Duke Blue Tint 1 RGB: 50 117 175 HEX: 3275af</div>	<div>UNC Blue Tint 1 RGB: 110 175 219 HEX: 6eafdb</div>	<div>Eggplant Tint 1 RGB: 115 60 125 HEX: 733c7d</div>	<div>CCPH Teal Tint 1 RGB: 66 186 180 HEX: 42bab4</div>	<div>Dark Gray Tint 1 RGB: 108 112 120 HEX: 6c7078</div>	<div>Orange Tint 1 RGB: 246 151 82 HEX: f69752</div>
<div>Duke Blue Tint 2 RGB: 102 151 195 HEX: 6697c3</div>	<div>UNC Blue Tint 2 RGB: 147 195 228 HEX: 93c3e4</div>	<div>Eggplant Tint 2 RGB: 150 109 157 HEX: 966d9d</div>	<div>CCPH Teal Tint 2 RGB: 114 203 199 HEX: 72cbc7</div>	<div>Dark Gray Tint 2 RGB: 145 148 154 HEX: 91949a</div>	<div>Orange Tint 2 RGB: 248 177 126 HEX: f8b17e</div>
<div>Duke Blue Tint 3 RGB: 153 186 215 HEX: 99bad7</div>	<div>UNC Blue Tint 3 RGB: 183 215 237 HEX: b7d7ed</div>	<div>Eggplant Tint 3 RGB: 202 182 206 HEX: cab6ce</div>	<div>CCPH Teal Tint 3 RGB: 161 220 217 HEX: a1dcd9</div>	<div>Dark Gray Tint 3 RGB: 181 183 187 HEX: b5b7bb</div>	<div>Orange Tint 3 RGB: 249 190 147 HEX: f9be93</div>
<div>Duke Blue Tint 4 RGB: 204 220 235 HEX: ccdceb</div>	<div>UNC Blue Tint 4 RGB: 219 235 246 HEX: dbebf6</div>	<div>Eggplant Tint 4 RGB: 229 221 226 HEX: e5dde2</div>	<div>CCPH Teal Tint 4 RGB: 208 237 236 HEX: d0edec</div>	<div>Dark Gray Tint 4 RGB: 218 219 221 HEX: dadbdd</div>	<div>Orange Tint 4 RGB: 251 216 190 HEX: fbd8be</div>
<div>Duke Blue Tint 5 RGB: 229 237 245 HEX: e5edf5</div>	<div>UNC Blue Tint 5 RGB: 237 245 250 HEX: edf5fa</div>	<div>Eggplant Tint 5 RGB: 247 245 248 HEX: f7f5f8</div>	<div>CCPH Teal Tint 5 RGB: 231 246 245 HEX: e7f6f5</div>	<div>Dark Gray Tint 5 RGB: 236 237 238 HEX: ecedee</div>	<div>Orange Tint 5 RGB: 252 229 212 HEX: fce5d4</div>

Indicator colors

<div>Spring Green RGB: 157 200 88 HEX: 9dc858</div>	<div>Marigold RGB: 223 197 0 HEX: dec500</div>	<div>Red RGB: 205 59 68 HEX: cd3b44</div>
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Fonts and Format

While following the RADx-UP Branding Guidelines, these data visualization guidelines take into consideration the resources “chart-makers” have available to them no matter how small the team. The purpose of creating the guidelines is to ensure visual consistency across the RADx-UP program data visualizations.

The font family selected for use in all data visualizations is *Trebuchet MS* (a system font available on both PC and OS operating systems).

Trebuchet MS Regular
Trebuchet MS Italic
Trebuchet MS Bold
Trebuchet MS Bold Italic

The chart to the right shows unique chart parts and their font specifications.

Chart Part	Font	Suggested Size	Color	Case
Figure Number	Trebuchet MS Regular		#484D57	ALL CAPS
Title	Trebuchet MS Regular	18/20 pt	#484D57	Sentence
Subtitle	Trebuchet MS Regular	12/20 pt	#484D57	Sentence
X- and Y-axis Titles	Trebuchet MS Bold Italic	10 pt	#484D57	ALL CAPS
X- and Y-axis Labels	Trebuchet MS Regular	10 pt	#484D57	Sentence
X- or Y-axis	-	1 pixel	#484D57	-
Gridlines	-	1 pixel	#E5EDF5	-
Direct Label	Trebuchet MS Regular	11 pt	#484D57	Sentence
Data Point Label	Trebuchet MS Regular	11 pt	#484D57	Sentence
Legend Title	Trebuchet MS Regular	10/14 pt	#484D57	Sentence
Legend	Trebuchet MS Regular	10/14 pt	#484D57	Sentence
Source and Notes	Trebuchet MS Regular	9/11 pt	#484D57	Sentence

6. Improving Accessibility With 508 Compliance

When creating dashboards, it is important to recognize and plan for Section 508 requirements and accommodations that need to be included in your products. These requirements ensure that content is accessible to, and usable by, individuals with disabilities.

508 compliance is required for:

The public website is required by Duke to adhere to 508 compliance (at level WCAG 2.0 Level AA). For the public website, the primary 508 compliance requirement elements are (1) color comparison such that the foreground is appropriately contrasted to background, and (2) providing alt text for static images embedded in the page. The alt text should describe the content in detail if it is not replicated elsewhere on the page in non-image format (such as a table). For example, if there is a bar chart, provide a breakdown in the alt text of each category and its respective value.

508 compliance is recommended for:

Content on password-protected websites, such as myRADx-UPhome, is recommended to adhere to 508 where possible/reasonable, but it is not required. When dashboards and data visualizations are embedded within myRADx-UPhome, especially within the firewall, 508 is preferred where possible, but not required.

7. Additional Resources

Want to learn more? Take a moment to review the following resources.

Data Visualization Overviews

Evergreen, S. D.H. (2019). *Effective data visualization: The right chart for the right data* (2nd ed.). <https://stephanieevergreen.com/books/>

Evergreen, S. D.H. (2017). *Presenting data effectively: Communicating your findings for maximum impact* (2nd ed.). <https://stephanieevergreen.com/books/>

Krum, R. (2014). *Cool infographics: Effective communication with data visualization and design*. John Wiley & Sons, Inc.

Lankow, J., Ritchie, J., & Crooks, R. (2012). *Infographics: The power of visual storytelling*. John Wiley & Sons, Inc.

Nussbaumer Knaflic, C. *Storytelling with data*. (Book and website.) <https://www.storytellingwithdata.com/>

Stones, C., & Gent, M. (2015). *The 7 G.R.A.P.H.I.C. principles of public health infographic design*. University of Leeds. <https://visualisinghealth.files.wordpress.com/2014/12/guidelines.pdf>

Wexler, S., Shaffer, J., & Cotgreave, A. (2017). *The big book of dashboards: Visualizing your data using real-world business scenarios*. John Wiley & Sons, Inc.

Yin, M., Hollender, D., Condelli, L., Shewitz, D., Duffy, A., & Movit, M. (2014). *The power of data visualization: Advanced presentations of NRS data*. U.S. Department of Education, Office of Vocational and Adult Education, Division of Adult Education and Literacy. https://nrsweb.org/sites/default/files/Data_Visualization_Guide_508.pdf

Equity Awareness and Addressing Common Pitfalls in Visualizations

Cairo, A. (2015). Graphics lies, misleading visuals: Reflections on the challenges and pitfalls of evidence-driven visual communication. In Bihanic, D. (Ed.), *New Challenges for Data Design*. https://faculty.ucmerced.edu/jyevea/classes/Spark/readings/Cairo2015_Chapter_GraphicsLiesMisleadingVisuals.pdf

Jones, B. (2019). *Avoiding data pitfalls: How to steer clear of common blunders when working with data*. <https://dataliteracy.com/avoiding-data-pitfalls/>

Schwabish, J., & Feng, A. (2021, June 9). *Do no harm guide: Applying equity awareness in data visualization*. Urban Institute. <https://www.urban.org/sites/default/files/publication/104296/do-no-harm-guide.pdf>

COVID-19-Related Resources

Peeples, L. (2022, March 23). *Lessons from the COVID data wizards*. Nature. <https://www.nature.com/articles/d41586-022-00792-2>

VISME. *COVID-19: A global health crisis infographic template*. <https://www.visme.co/templates/infographics/covid19-a-global-health-crisis-infographic-1425281632/>

Cairo, A. (2019). *How charts lie: Getting smarter about visual information*. <https://albertocairo.com/>

8. Acknowledgments

The development of this guide was supported by the National Institute on Minority Health and Health Disparities of the National Institutes of Health under award number U24MD016258. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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