

# chapter 7 scatterplots association correlation

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## Chapter 7: Scatterplots, Association, and Correlation

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When you first encounter data analysis, you might think that the most important thing is simply to collect numbers. Yet, the way those numbers are presented can reveal patterns, relationships, and insights that would otherwise remain hidden. In Chapter 7 of many introductory statistics textbooks, the focus turns to **scatterplots, association, and correlation**—three foundational concepts that help analysts, researchers, and students make sense of complex data sets. This article walks through each of these ideas in depth, explains how they interconnect, and demonstrates how to apply them using real-world examples. By the end, you'll have a solid grasp of why scatterplots matter, how association differs from correlation, and how to compute and interpret correlation coefficients with confidence.

### Why Chapter 7 Matters in the Data Science Curriculum

Modern data science is built on the idea of turning raw observations into actionable knowledge. Before you can build predictive models or uncover causal mechanisms, you need to explore the data. Chapter 7 traditionally occupies a pivotal position because it bridges the gap between descriptive statistics—means, medians, and frequencies—and inferential techniques like regression and hypothesis testing. The concepts introduced here are:

- Scatterplots—visual tools that let you see relationships between two quantitative variables.
- Association—a broad, qualitative description of how two variables might be related.
- Correlation—a numeric measure that quantifies the strength and direction of a linear relationship.

By mastering these topics, you gain a powerful lens for spotting trends, identifying outliers, and preparing data for more sophisticated analyses. Moreover, many industries—from finance to public health—rely on scatterplots and correlation coefficients to inform decisions. Understanding Chapter 7 equips you with the language and skills to communicate findings effectively to both technical and non-technical audiences.

### Building a Scatterplot from Scratch

A scatterplot is the simplest yet most informative type of data visualization when dealing with two numeric variables. It plots each observation as a point on a Cartesian plane, with one variable on the horizontal axis (x-axis) and the other on the vertical axis (y-axis). The arrangement of points tells a story: do they cluster along a line, curve, or spread randomly?

1. **Gather Data:** Ensure you have two quantitative variables measured on the same observations. For example, height and weight of a group of adults.
2. **Choose Axes:** Decide which variable you want to emphasize. Common practice is to put the independent variable (often time or a predictor) on the x-axis.
3. **Plot Points:** For each observation, draw a dot at coordinates (x, y).
4. **Add Labels:** Title the plot, label axes with variable names and units, and optionally add a legend if you have categories.
5. **Inspect the Pattern:** Look for linear trends, clusters, or outliers.

Many software packages automate these steps. In Python, you might use `matplotlib.pyplot.scatter` or Seaborn's `scatterplot`. In R, `ggplot2`'s `geom_point()` is a go-to. But the underlying logic remains the same: each dot represents

a single data point.

- Color Coding: Differentiate groups (e.g., gender, treatment vs. control) by color.
- Shape and Size: Encode additional variables using point shape or size.
- Regression Line: Overlay a best fit line to highlight linear association.
- Confidence Bands: Shade areas around the regression line to indicate uncertainty.
- Interactive Features: Use tools like Plotly or Bokeh to enable zooming and tooltips.

These enhancements can transform a simple scatterplot into a rich storytelling device that conveys multiple dimensions of information at a glance.

## Association: A Qualitative Lens

Before quantifying relationships, analysts often ask a qualitative question: *Is there an association between variable A and variable B?* Association refers to any systematic relationship, regardless of its strength or direction. It can be positive, negative, or non linear. For instance, there might be a strong association between exercise frequency and heart rate, but the relationship could be curvilinear rather than straight line.

- Positive Association: As one variable increases, the other tends to increase.
- Negative Association: As one variable increases, the other tends to decrease.
- Zero Association: No discernible pattern; variables appear independent.
- Non Linear Association: The relationship follows a curve, such as a quadratic or exponential pattern.

Recognizing association is the first step toward deeper analysis. It prompts further questions: Are there confounding variables? Is the relationship causal? Does it hold across subgroups?

## Correlation: Quantifying Association

While association is a descriptive concept, correlation assigns a numerical value that captures both the direction and the strength of a linear relationship. The most commonly used correlation coefficient is Pearson's  $r$ , defined as:

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2 \sum_{i=1}^n (y_i - \bar{y})^2}}$$

where  $x_i$  and  $y_i$  are individual observations, and  $\bar{x}$  and  $\bar{y}$  are the means of the respective variables.

- $r = 1$ : Perfect positive linear relationship.
- $r = -1$ : Perfect negative linear relationship.
- $r = 0$ : No linear relationship.
- Values between -1 and 1 indicate varying degrees of linear association.

It's important to remember that correlation does not imply causation. Two variables can be highly correlated due to a third, underlying factor or simply by chance.

- Spearman's Rank Correlation: Measures monotonic relationships, useful when data are not normally distributed or contain outliers.
- Point Biserial Correlation: Used when one variable is continuous and the other is binary.
- Kendall's Tau: Another rank based correlation, often preferred for small sample sizes.

Choosing the right correlation metric depends on data characteristics and research questions.

## Computing Correlation Coefficients in Practice

Let's walk through a practical example using a sample dataset of students' study hours and exam scores. We'll compute Pearson's  $r$  in both R and Python to illustrate the process.

```

import pandas as pd
import numpy as np

# Sample data
data = pd.DataFrame({
    'study_hours': [1, 2, 3, 4, 5, 6, 7, 8, 9, 10],
    'exam_score': [55, 58, 60, 65, 68, 70, 73, 75, 78, 80]
})

# Compute Pearson correlation
r = np.corrcoef(data['study_hours'], data['exam_score'])[0, 1]
print(f"Pearson's r: {r:.3f}")

```

Output:

Pearson's r: 0.996

Such a high  $r$  indicates a very strong positive linear relationship between study hours and exam scores.

```

# Sample data
study_hours <- 1:10
exam_score <- c(55, 58, 60, 65, 68, 70, 73, 75, 78, 80)

# Compute Pearson correlation
r <- cor(study_hours, exam_score)
print(paste("Pearson's r:", round(r, 3)))

```

Output:

Pearson's r: 0.996

Both languages confirm the same result, illustrating the robustness of the correlation calculation.

### Assessing Significance: Is the Correlation Real?

Even a high correlation coefficient can arise by chance, especially with small sample sizes. To evaluate statistical significance, we calculate a  $p$  value based on a  $t$  distribution:

$$t = r / \sqrt{[(n - 2) / (1 - r^2)]}$$

where  $n$  is the number of observations. The  $p$  value tells us the probability of observing such a correlation if the true correlation were zero.

Using the previous example with  $n = 10$  and  $r = 0.996$ :

```
t = 0.996 * sqrt((10 - 2) / (1 - 0.996**2))
p_value = 2 * (1 - pt(abs(t), df=8))
```

The resulting p value is extremely small (

### Common Pitfalls and How to Avoid Them

- **Outliers Distorting the Correlation:** A single extreme point can inflate or deflate  $r$ . Always examine scatterplots for outliers before computing correlation.
- **Assuming Linearity:** Pearson's  $r$  only captures linear relationships. If the scatterplot suggests a curve, consider Spearman's rank or a nonlinear model.
- **Small Sample Size:** With fewer than 30 observations, the sampling distribution of  $r$  can be skewed, leading to unreliable  $p$  values.
- **Ignoring Causality:** Correlation is not causation. Complement correlation analysis with domain knowledge, experimental design, or causal inference methods.
- **Misinterpreting Zero Correlation:** A correlation of zero does not guarantee independence; the variables could still be related in a non-linear way.

### Applying Scatterplots, Association, and Correlation in Real-World Projects

Researchers often explore the relationship between lifestyle factors (e.g., smoking, diet) and health outcomes (e.g., blood pressure). Scatterplots reveal patterns; correlation coefficients quantify risk. For instance, a study might find a moderate negative correlation between fruit consumption and LDL cholesterol levels, suggesting a protective effect.

In portfolio management, analysts examine the correlation between asset returns to diversify risk. A low or negative correlation between stocks and bonds can reduce portfolio volatility. Scatterplots help visualize co-movement, while correlation matrices summarize pairwise relationships.

Marketers track the association between advertising spend and sales revenue. A scatterplot can reveal diminishing returns, and the correlation coefficient quantifies the strength of the relationship. These insights inform budget allocation strategies.

### Integrating Scatterplots and Correlation into Statistical Modeling

Before building regression models, data scientists perform exploratory data analysis (EDA

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