PART I

Introduction

CHAPTER 1

Introduction to Making Sense of Numbers

Learning Objectives

After reading this chapter, you will be able to do the following:

1. Recognize the scope of topics and applications for which numbers are used.
2. Identify common tasks for using numbers to answer real-world questions.
3. Define plausibility and how it relates to making sense of numbers.
4. Anticipate some challenges of learning to make sense of numbers.
5. List ways people typically learn about the applied use of numbers.

The Many Uses of Numbers

Numbers are used as evidence about a huge variety of topics in today's complex global society. For instance, being able to interpret numeric information helps you understand issues such as whether a proposed increase to the minimum wage will mean fewer entry-level jobs in your area or whether e-cigarettes are less risky for your health than conventional cigarettes. Knowing how to work with numbers gives you the tools to make important decisions like how to save toward buying a car or other major purchase. Being able to recognize how data were collected and analyzed can help you distinguish between "fake news" and reliable information from the media and other sources. Understanding what numbers mean for a social issue can motivate you to take action, such as advocating for change after reading about inequitable treatment of certain groups in society.

It takes only a quick scan of today's media to see just how many aspects of life require you to understand and apply numeric information. For instance, a major newspaper might feature cover stories on national election results, cancer rates, Chinese population trends, elementary school education, and crime, each of

which present and discuss several numeric facts. Other sections of that day's paper might include articles on the stock market, a few scientific topics, the economy, wages, housing, the environment, several sports, the weather, and many other topics that involve various numeric facts and patterns. That is a lot of different topics (and numbers) to become familiar with!

> Numbers provide important information for addressing many different issues and tasks in school, everyday life, and in the workplace.

A key objective of this book is to teach you how to avoid making common errors of logic, calculation, and interpretation by introducing a systematic approach and a healthy dose of skepticism to understanding and applying the numbers you encounter.

Common Tasks Involving Numbers

As you go through your everyday life at school, in your job, or doing volunteer work, you will need to use numbers in several different ways. You might use numeric facts to make decisions. Suppose you see an ad for a new cell phone plan that looks really cheap. To make an informed choice about whether it is worth changing from your current plan with a different provider, you will need to do some research to find and compare several pieces of numeric data for the two plans, including the type of phone or device, whether the pricing is based on usage (e.g., gigs/month) or a flat rate per month, whether you are locked in for a long term (like two years), and the cost of early termination penalties.

Another common task is doing simple comparisons using numeric facts from books, reports, or websites. Perhaps your first job after college is at an environmental monitoring company and your supervisor has asked you to find some statistics about water quality in a nearby lake and to present those numbers at a staff meeting. To do that job well, you need to know what information to look for, how to find comparison values to help interpret the measures of water quality such as levels of pH or bacteria in the water, and be able to communicate the results clearly to the people who will attend the meeting.

A third common task is analyzing a set of data that someone else has collected. Suppose your economics professor assigns you to use data from a government survey to test whether differences in unemployment rates show real differences between occupations or whether those variations could be explained by random variation. To ace that assignment, you need to do some research on how the data were collected and how unemployment was measured, be able to identify and conduct the relevant types of statistical tests, and know how to write up the results in ways that answer the professor's question.

A fourth type of research task is collecting quantitative data. Imagine that you have a summer internship at a marketing firm where you are asked to design and carry out a survey of 400 consumers to learn about their preferences among three different brands of potato chips. To convince that company to hire you for a permanent job, you need to know how to design the study and write the questions to collect data in a form that can be used to answer the questions your supervisor has posed.

A fifth common task is communicating numeric results. Suppose you are working for an organization that lobbies for better housing for low-income families. To enlist new volunteers and persuade potential funders to donate to that cause, your supervisor asks you to design some snappy charts and social media messages to get the word out about the issues and what people can do to help. To be effective at your job, you need to know how to identify and communicate a few key numbers using charts and prose that will quickly and clearly convey the seriousness of the issues to your intended audiences.

To become adept at identifying, assessing, calculating, interpreting, and presenting numbers, you must master a set of concepts and skills that prepare you to think critically about numbers. You need to know how the topic, context (setting), and ways things were measured attach meaning to numbers so you can interpret and use that information. You need to be able to identify which calculations and contrasts are best suited for answering the questions of concern to you. You need to know how to assess the quality of numeric estimates and understand enough about statistical tests that you can grasp the meaning of those numbers without guidance from experts. Finally, you need to be able to write or speak about numeric information in ways that allow your audience to make sense of the numbers and understand how they help answer the question at hand.

Common quantitative research tasks include interpreting numbers that you read about, analyzing data that others have collected, collecting data, and communicating numeric results to others.

Plausibility of Numeric Values

Making sense of numbers involves figuring out what values are **plausible** (realistic) for the topic, setting, and way of measuring whatever is being quantified, be it price, population growth, temperature, or other characteristic. A value that is well-suited for some topics or settings might be totally absurd—**implausible**—for others. In other words, not all numeric values fit all topics, contexts, and ways of measuring things.

A **plausible** numeric value is one that is possible and realistic for the particular topic, context, and way of measuring.

Although numeric information is widely used, many newspaper articles, blogs, websites, and even scientific papers sometimes present numeric facts without enough information to help readers understand what those numbers mean. They report what I call "naked numbers"—facts reported without context or interpretation. For instance, is a price advertised by a local vendor cheap or expensive? Do trend data suggest rapid or slow population growth? Is today's temperature typical for the season and location or one that suggests climate change?

Challenges in Making Sense of Numbers

For some topics, you know from experience which numeric values make sense. For instance, you probably have a good idea how much a concert ticket costs and what temperatures to expect in your hometown in winter. However, you might have heard your grandparents lament how much cheaper it was to go to a concert "back in the day," and if you've gone on a trip to another part of the country over winter break, maybe you didn't know what clothes to pack for the weather there. In other words, which numeric values make sense and how you interpret them often depend on time and place as well as topic.

When you run into a new topic, the fact that you don't know how it was measured, what typical levels are, and how much those values vary make it really hard to understand what a particular numeric value means. For instance, suppose your friend goes to the doctor and learns that he has diabetes. For the first time, he has to interpret and make decisions based on information about his A1C level so he can learn to manage his condition. Most newly diagnosed diabetics will have no idea what A1C measures, what constitutes a "good" or "bad" level of A1C, or how much of a change (or in what direction) would represent a meaningful improvement. Without understanding those things, how can your friend know whether his efforts to control his diabetes are working?

Making it even more challenging to interpret numeric information is the fact that a particular number can have very different meanings depending on whether it is a single data point (such as the price of a certain style of jeans at your favorite store), a summary statistic for a set of data points (such as the average price of jeans at several different stores), a mathematical contrast (such as how the price of jeans has changed over time), or the result of an inferential statistical test (such as whether there is a statistically significant difference in the price of jeans from bricks-and-mortar stores versus online stores).

A value or difference between values that is "big" for one topic, context (place, time, and group), and type of units might be "small" for another topic, context, or units.

- A value of 10,000 is possible if counting the number of people in a town but impossible as the height of a person in inches.
- A final score of 105 to 98 makes sense for basketball but is way too high for ice hockey. On the other hand, a score of 3 to 0 would be a pretty typical score for a hockey game, but outrageously low for any but a preschool basketball game. And it is a rout when an international football (soccer) team wins by 3 points, but a close game when a U.S. football team wins by the same margin.

The type of measure, calculation, or contrast also determines which numeric values do (and do not) make sense.

- Certain numeric measures can only take on positive values or can only be counted in whole numbers. For example, the number of students in your class cannot be negative or include fractions of people.
- On the other hand, the change in number of students between the beginning and end of the school year could be negative if some people dropped out or moved away, and average class size at your school could include decimal places (e.g., 24.7 students per class).

> Not all numeric values fit all topics, contexts, or ways of measuring and analyzing data, so it is important to learn how to determine which values make sense for whatever, whenever, and whomever you are studying and in whatever way you are measuring the concepts.

Making sense of numbers also involves knowing whether higher values represent an improvement or deterioration in whatever you are measuring.

- For some things, a higher score is better. For example, a higher credit rating will help you qualify for credit cards, more favorable interest rates on loans, and other financial advantages.
- For other topics, a lower score is what you're aiming for. For instance, you want to minimize points added to your driver's license because more points mean higher car insurance premiums and greater chances of your driving privileges being revoked.

For many topics and research questions, there are numeric cutoffs and benchmarks that help us interpret what a particular numeric value means for that topic and units. Numeric goals, thresholds, and standards can also help convey whether a particular numeric value is high or low, favorable or unfavorable. You will learn more about cutoffs, thresholds, and target values in Chapter 8.

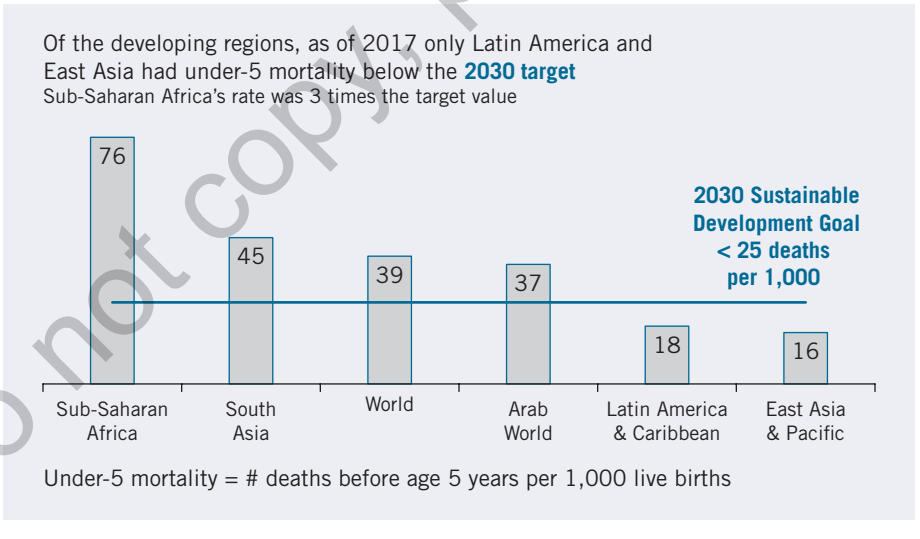
Example: The value 32 °F is the freezing point of water.

*Although that **threshold** is highly relevant for topics related to physical properties of water, there probably aren't many other **topics** for which the value "32" is relevant for defining a concept or differentiating between meaningfully different categories. Besides, 32 °C (Celsius) = 89 °F (Fahrenheit), and the freezing point of water is 0 °C, so clearly knowing the **units** matters as well.*

Example: The World Bank set a goal for the year 2030 of reducing child mortality rates to less than 25 deaths per 1,000 children under age 5 years. Figure 1.1 shows how each of the world's developing regions 2017 child mortality rates compared to that target.

*By viewing which regions' child mortality rates remain above the **target** and by how much, policymakers can identify which regions need the most resources to meet that **goal**.*

Figure 1.1 Observed Mortality Compared to a Sustainable Development Goal



Source: Data from World Bank (2018). © World Bank. License: CC BY 3.0 IGO.

A Cautionary Tale

The following true story underscores how crucial it is to learn how to interpret the numeric values that relate to a particular topic, units, and setting before you work with those numbers. A young researcher was analyzing infant birth weight using survey data from a developing country from the year 2002, which she had downloaded from a website but hadn't learned much about before she started analyzing it. In the sample of cases she was studying, birth weight values ranged up to 9,999 with an average of about 8,000. Had she taken the time to look up the expected range of values for that concept (birth weight) and units (grams), she would have immediately seen a red flag because 9,999 grams is roughly 22 lbs.—a typical weight for a 1-year-old child (Figure 1.2a), not a newborn baby (Figure 1.2b)!

Figures 1.2a and 1.2b The Importance of Checking Whether Numbers Make Sense for the Topic and Units

Notes:

a. A 1-year-old, average weight approx. 22 lbs. (9,999 grams)

b. A newborn, average weight approx. 7.5 lbs. (3,409 grams)

Source: iStock.com/JBryson, iStock.com/USGirl.

In addition, it turned out that the birth weight question was not asked about children who were 5 to 17 years old at the time of the survey, so kids those ages were given the value "9999" as shorthand to indicate that birth weight information was missing for them. Once the student researcher learned what those 9999s meant, she had to redo all the analyses for her final paper at the last minute, excluding the cases with missing values so that the remaining numbers could be interpreted as actual birth weight in grams. This book will help you avoid those kinds of mistakes and all that stress by teaching you the right questions to ask about the numbers for your topic and data before you use them!

How We Learn to Make Sense of Numbers

We learn how to make sense of numbers in several ways, including formal instruction, on-the-job training, and experiential learning. Some topics are taught in school. For instance, you learned the basics of how to tell time in preschool and how to recognize common monetary denominations and make change in elementary school. Within your major area of study in college, you take courses that familiarize you with the key numeric concepts and measures in that field. For example, if you are majoring in economics, you will learn how to calculate and interpret things such as interest rates, measures of labor force participation, and inflation. If your roommate is a premed student, she will instead learn about numeric concepts in biology, chemistry, and physics.

We learn about some other numeric topics through on-the-job training. For instance, someone with a new job in retail will learn about sales commissions and how they affect their earnings, whereas a trainee in the mental health services field will be taught how to interpret data from questionnaires used to screen for depression or anxiety.

Obviously, you can't be formally taught about the numbers used in every topic; there are just too many subjects for which numbers are used, as you can see from the examples used so far in this book. Besides, people's interests and jobs change, and new topics and measures emerge all the time. For instance, in 2005, personal "data usage" was a completely irrelevant concept, but by 2015 that term was widely understood by just about everyone over the age of 12! Also, standards and thresholds used to interpret numbers for various topics are updated every now and then. For example, recommendations about healthy blood pressure ranges were revised in 2017 by medical experts based on the latest research.

In other situations, we learn about numeric topics through educational pamphlets or websites, sometimes with guidance from an expert, other times on our own. Social services offices have brochures to familiarize clients with eligibility criteria for programs such as the Supplemental Nutrition Assistance Program (SNAP) or childcare tax credit. Banks and nongovernmental organizations (NGOs) disseminate information about microloans to potential borrowers in a variety of formats. WebMD and other health-related websites have fact sheets that people can download to learn about the numeric measures related to a particular disease and the chances of recovery for each of several treatment options.

You might have learned about other numeric measures experientially, often as hobbies you share with friends or family members or perhaps through intensive individual "study." A budding baseball fan gradually learns the various statistics that pertain to that sport from reading the sports section and listening to commentators: what each statistic measures, whether higher numbers are good (batting average) or bad (earned run average—ERA), what range of values is possible for each measure, and what level typically earns a player a Cy Young award or Golden Glove award versus what value will get them sent down to the minor leagues. An aspiring cookie

baker will quickly learn that although sugar is often measured in cups, salt should be measured in teaspoons.

However, your interests are likely to change over time and might be different from those of your family members or friends. That means that you can't always rely on a relative or friend to teach you how to interpret statistics about an unfamiliar sport such as bocce or cricket, or count on knowing someone who can explain how to measure the ingredients used to brew beer. These issues mean that it is vital that you master a set of research concepts and critical-thinking skills so you will be prepared to teach yourself how to understand and interpret numbers for many different topics and applications.

> With numbers and quantitative analysis used for so many different issues, it is impossible to be formally taught how to use and interpret numbers for every issue. As a consequence, it is important to master the research and quantitative reasoning skills needed to make sense of numbers for new topics you encounter.

Hopefully, this introduction has convinced you that in your daily life, in school, and at work, you will encounter many different topics for which numbers are essential, some of which will be unfamiliar to you. Obviously, you want to avoid a haphazard approach to learning about the relevant numbers for each topic, which could be very confusing, waste a lot of time, and allow for many mistakes. To help you be more efficient and effective at teaching yourself about numbers for topics that are new to you, in this book I define and illustrate a series of research methods and quantitative reasoning principles. I also show how concepts and skills from other disciplines—including fields from which the topic is drawn, basic statistics, and expository writing—will help you learn to make sense of numbers.

TERMS AND CONCEPTS

Benchmark 7
  Threshold 7
  Target 7
Context 4
  Setting 4
Implausible (impossible, unrealistic) value 4
Plausible (possible, reasonable, believable) numeric value 4
Quantitative reasoning 10
  Critical thinking 10
Topic 7
Units 7

HIGHLIGHTS

- Being able to **make sense of numbers** is a critical skill set for addressing many different issues and tasks in school, daily life, and in the workplace.
- **Quantitative research tasks** include **interpreting numbers** that you read about, **analyzing data** that others have collected, **collecting data**, and **communicating** numeric results to various audiences.
- Not all numeric values fit all **topics**, **contexts**, or **ways of measuring** and **analyzing data**, so it is important to learn ways to distinguish between values that are **plausible** (make sense) and those that are not.
- Although some numeric tasks are taught as part of **formal education** or **training**, others require that you be prepared to teach yourself how to use and interpret numbers to suit new topics and tasks.
- Making sense of numbers involves concepts and skills from **many different fields**.

EXERCISES

Individual Exercises

Quantitative Reasoning in Everyday Life

1. Describe courses, paid or volunteer positions, or other situations where you've been asked to do the following tasks: (a) use numbers from published or online sources, such as choosing which of several brands to buy; (b) analyze a set of data, such as calculating a rate, average, or change over time; (c) collect numeric data, such as conducting a survey; and (d) presenting numeric information using words, a chart, or other diagram.

   [Example answer to (d): As a volunteer for my local congresswoman, I was asked to create a chart comparing the costs of solar, wind, and coal power sources.]

2. For each of the tasks you listed in answer to the previous question, describe which aspects of conducting those tasks you found challenging.

3. Describe an example of when you've been asked to learn about numbers in each of the following ways, including information on the topic, measure, method of learning, and source of information: (a) been formally taught about numeric measures for a specific topic—for example, in a course at school; (b) been taught about numeric measures for a task outside of school—for example, by a supervisor at a job or volunteer position; (c) learned about numeric measures for an unfamiliar topic by reading a website or brochure; and (d) learned from a friend or taught yourself about numeric measures for a new interest or hobby.

   [Example answer to (d): I learned how to complete a baseball box score (including runs, hits, errors, strikeouts, bases on ball) by attending games with my uncle.]

4. For each of your answers to the previous question, list aspects of making sense of the numbers that you found challenging.
5. Think of a situation in which you were given numeric information about a topic, setting, or type of measure that was unfamiliar to you. Identify the resources you used or could have used (e.g., people, websites, reference materials) to figure out what values were plausible for those numbers.
6. Think of a situation in which you misunderstood the meaning of a numeric measure or its value. Describe how you (or someone else) caught your error and what you did to learn the correct understanding of that number.

Group Exercises

Quantitative in Everyday Life

7. Make a list of the tasks your group members identified for Exercise 1 above. Then compare the aspects of making sense of numbers in those tasks that you found challenging (from Exercise 2).
8. Repeat the instructions to the previous question but for your answers to Exercise 3.
9. Repeat the instructions to Exercise 7 but for your answers to Exercise 5.
10. Identify a numeric measure of some aspect of COVID-19. Discuss the types of resources you used (or could have used) to learn how to interpret the meaning of those numbers.