Chapter 1: Why Numbers Do Not Speak for Themselves

In August of 1985, engineers at the contractor Morton Thiokol International wrote the following memo to NASA officials:

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| Per your request, this letter contains the answers to the two questions you asked at the July Problem Review Board telecom:   1. *Question:* If the field joint secondary seal lifts off the metal mating surfaces during motor pressurization, how soon will it return to a position where contact is re-established?   *Answer:* Bench test data indicated that the o-ring resiliency (its capability to follow the metal) is a function of temperature and the rate of case expansion. MTI measured the force of the O-ring against Instron platens, which simulated the nominal squeeze on the o-ring and approximated the case expansion distance and rate.  At 100oF the O-ring maintained contact.  At 75oF the O-ring lost contact for 2.4 seconds.  At 50oF the O-ring did not reestablish contact for ten minutes at which time the test was terminated.  The conclusion is that the secondary sealing capability in the SRM field joint cannot be guaranteed.   1. *Question:* If the primary o-ring does not seal, will the secondary seal seat in sufficient time to prevent joint leakage?   *Answer:* MTI has no reason to suspect that the primary seal would ever fail after pressure equilibrium is reached, i.e., after the ignition transient. If the primary o-ring were to fail from 0 to 170 milliseconds, there is a very high probability that the secondary o-ring would hold pressure since the case has not expanded appreciably at this point. If the primary seal were to fail from 170 to 330 milliseconds, the probability of the secondary seal holding is reduced. From 330 to 660 milliseconds the chance of the secondary seal holding is small. This is a direct result of the o-ring's slow response compared to the metal case segments as the joint rotates. |

**Figure 1.1: Memo from MTI engineers to NASA (**Winsor, 1988)

Less than six months after receiving this memo from MTI, NASA launched the Challenger space shuttle at a temperature of 18o F. The shuttle exploded a mere 73 seconds after take-off, killing all seven members of the crew, including the first and only civilian ever to accompany a NASA space mission—the schoolteacher Christa McAuliffe. The *Challenger* disaster put NASA into a public-relations crisis from which it has never recovered.

A task force found that the cause of the *Challenger* disaster was a faulty O-ring seal on the solid rocket boosters developed by MTI. An appendix to the task force report notes that while managers estimated a 1 in 100,000 probability estimate of flight failure and loss of life on the Challenger, engineers had estimated a 1 in 100 probability. Moreover, engineers clearly recognized the problems with the low launch temperature. One MTI engineer was reported to have said "what business does anyone even have thinking about 18 degrees? We’re in no man’s land’" (Bergin, 2007).

Figure 1.2: Smoke plume after the break up of the Challenger Space Shuttle

The memo in Figure 1.1 is far from the only warning made about the O-ring seals that caused the space shuttle to go down in NASA’s biggest public relations crisis. However, it clearly points to the problems with the O-ring seal, particularly in cold temperatures. But when NASA officials were later queried about this memo, they replied:

"I don't know if anybody at that time understood the joint well enough to realize that the data was crucial"

"There were a whole lot of people who weren't smart enough to look behind the veil and say, 'Gee, I wonder what this means.'"

"I didn't realize the data's significance"

"It sounded like old news"

As the memo in Figure 1.1 illustrates, numbers are not self-evident facts that speak for themselves. The managers at NASA are technologically literate; yet, they were not able to see the implications of the numbers MTI engineers presented. They read the data, but they did not understand its significance and, consequently, did not take actions that may have saved lives.

Clearly, to be effective technical, scientific, or business professionals we need not just hard data to support our claims, but also methods for communicating the significance of that data to our audience.

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| **Exercise 1.1: The Challenger memo**  Look at the memo in Figure 1.1 and locate the places where the MTI engineers signal problems with the O-ring seal. Why do you think NASA officials failed to realize the importance of this data? What could the engineers have done to better communicate problems with the seal without sounding alarmist or emotional? |

**Data and Argument**

If we were to draw a continuum with emotion at one end and logical reasoning at the other, most people would place data on the logical reasoning end. Data is associated with facts, evidence and cool, hard, logic. Yet there is an emotional component to how we present data.

Consider the following conversation I had with a pregnant friend worried by research on the effects of maternal age. My friend reported being particularly alarmed by a statistic stating that one in fifty pregnancies by women over 35 will result in an abnormal fetus. However, when she shared her fears with her doctor, she was told there was a 97% probability her unborn child will have no problems. My friend left her doctor’s office reassured that her pregnancy would be fine and annoyed at the sources that had unnecessarily alarmed her.

The problem with this reasoning is that the number quoted by the doctor—and the number that reassured my friend—was actually a *worse* statistic than the one that had alarmed her. One-in-fifty translates to two-in-one hundred, or a 98% likelihood that everything will be fine. Thus, the doctor's reassurance that she had a 97% chance of escaping this health risk is slightly worse than the number that had worried her.

Why did my friend find one number alarming and another, slightly worse, number reassuring? One-in-fifty, the statistic that alarmed her, is easy to visualize. We all know 50 people; it is easy to imagine one of these fifty experiencing a tragic event. By contrast, 97% is abstract and much harder to visualize. It is also a number that years of school have conditioned us to equate with success: a grade of 97% is an occasion for self-congratulation.

In other words, the same number presented two different ways can have very different effects on the audience. Writers select and present data that will persuade readers to act or respond in particular ways. This is why when someone tries to sell us a raffle ticket, they might say “You have a one-in-twenty chance of winning,” but never, “You have a 95% chance of losing,” even though the two statistics are mathematically equivalent.

Even when we are discussing data collected for scientific research, we are still persuading. We want readers to believe our results are valid and our findings interesting. We want them to believe we have made a significant contribution to scientific knowledge.

How we present data therefore depends upon our **purpose** and whether we want to, for instance, alarm or reassure our readers. It also depends upon the knowledge and needs of our **audience**: technical readers, for instance, will want more detail and fine-grained analysis than more causal readers. Data will also be presented differently depending on the **context:** the same information will be presented differently in a scientific journal than in a public presentation.

Finally, because readers tend to be skeptical, we must present data in a manner that earns our readers’ **trust**. While displaying data to emphasize certain points in line with our purpose, we need to ensure that we are ethical in how we represent certain trends and we make arguments that our audience will find credible.

We can therefore think about the data we present as at the center of four interrelated—yet sometimes competing—concerns. Figure 1.2 illustrates this relationship.

**Audience**

**Context**

**Data**

**Purpose**

**Trust**

**Figure 1.2: How we present data depends upon our purpose, audience, context, and the need to earn our readers’ trust**

Data is at the center of this relationship because there are core facts in our data that we must be accountable to. We cannot knowingly mislead a reader about the raw numbers we have collected. For instance, if we observe surgeons performing 100 procedures and note 10 errors, we cannot change the fact of that data. But we can make a decision to present that data as

*One in ten surgical procedures contained a physician error*

or

*90% of surgical procedures were error-free.*

Our choice about how to present this data will depend on our purpose, audience, context, and need to gain the reader’s trust.

Tables 1.1 and 1.2 provide another example of how we can present the same data differently to accommodate various purposes. These tables contain two different ways of presenting the same data on medals earned at the 2008 Summer Olympics. One of these tables is used by the International Olympic Committee and the other is preferred by most U.S. newspapers. Can you guess which is which?

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| **Table 1.1: 2008 Olympic medals by country** | **Table 1.2: 2008 Olympic medals by country** |
| | ***Country*** | ***Gold*** | ***Silver*** | ***Bronze*** | ***Total*** | | --- | --- | --- | --- | --- | | http://upload.wikimedia.org/wikipedia/commons/thumb/f/fa/Flag_of_the_People%27s_Republic_of_China.svg/22px-Flag_of_the_People%27s_Republic_of_China.svg.png [China](http://en.wikipedia.org/wiki/China_at_the_2008_Summer_Olympics) | **51** | 21 | 28 | 100 | | http://upload.wikimedia.org/wikipedia/en/thumb/a/a4/Flag_of_the_United_States.svg/22px-Flag_of_the_United_States.svg.png USA | **36** | 38 | 36 | 110 | | http://upload.wikimedia.org/wikipedia/en/thumb/f/f3/Flag_of_Russia.svg/22px-Flag_of_Russia.svg.png [Russia](http://en.wikipedia.org/wiki/Russia_at_the_2008_Summer_Olympics) | **23** | 21 | 29 | 73 | | http://upload.wikimedia.org/wikipedia/en/thumb/a/ae/Flag_of_the_United_Kingdom.svg/22px-Flag_of_the_United_Kingdom.svg.png [Britain](http://en.wikipedia.org/wiki/Great_Britain_at_the_2008_Summer_Olympics) | **19** | 13 | 15 | 47 | | http://upload.wikimedia.org/wikipedia/en/thumb/b/ba/Flag_of_Germany.svg/22px-Flag_of_Germany.svg.png [Germany](http://en.wikipedia.org/wiki/Germany_at_the_2008_Summer_Olympics) | **16** | 10 | 15 | 41 | | http://upload.wikimedia.org/wikipedia/en/thumb/b/b9/Flag_of_Australia.svg/22px-Flag_of_Australia.svg.png [Australia](http://en.wikipedia.org/wiki/Australia_at_the_2008_Summer_Olympics) | **14** | 15 | 17 | 46 | | http://upload.wikimedia.org/wikipedia/commons/thumb/0/09/Flag_of_South_Korea.svg/22px-Flag_of_South_Korea.svg.png [S. Korea](http://en.wikipedia.org/wiki/South_Korea_at_the_2008_Summer_Olympics) | **13** | 10 | 8 | 31 | | | ***Country*** | ***Gold*** | ***Silver*** | ***Bronze*** | ***Total*** | | --- | --- | --- | --- | --- | | http://upload.wikimedia.org/wikipedia/en/thumb/a/a4/Flag_of_the_United_States.svg/22px-Flag_of_the_United_States.svg.png USA | 36 | 38 | 36 | **110** | | http://upload.wikimedia.org/wikipedia/commons/thumb/f/fa/Flag_of_the_People%27s_Republic_of_China.svg/22px-Flag_of_the_People%27s_Republic_of_China.svg.png [China](http://en.wikipedia.org/wiki/China_at_the_2008_Summer_Olympics) | 51 | 21 | 28 | **100** | | http://upload.wikimedia.org/wikipedia/en/thumb/f/f3/Flag_of_Russia.svg/22px-Flag_of_Russia.svg.png [Russia](http://en.wikipedia.org/wiki/Russia_at_the_2008_Summer_Olympics) | 23 | 21 | 29 | **73** | | http://upload.wikimedia.org/wikipedia/en/thumb/a/ae/Flag_of_the_United_Kingdom.svg/22px-Flag_of_the_United_Kingdom.svg.png [Britain](http://en.wikipedia.org/wiki/Great_Britain_at_the_2008_Summer_Olympics) | 19 | 13 | 15 | **47** | | http://upload.wikimedia.org/wikipedia/en/thumb/b/b9/Flag_of_Australia.svg/22px-Flag_of_Australia.svg.png [Australia](http://en.wikipedia.org/wiki/Australia_at_the_2008_Summer_Olympics) | 14 | 15 | 17 | **46** | | http://upload.wikimedia.org/wikipedia/en/thumb/b/ba/Flag_of_Germany.svg/22px-Flag_of_Germany.svg.png [Germany](http://en.wikipedia.org/wiki/Germany_at_the_2008_Summer_Olympics) | 16 | 10 | 15 | **41** | | http://upload.wikimedia.org/wikipedia/en/thumb/c/c3/Flag_of_France.svg/22px-Flag_of_France.svg.png [France](http://en.wikipedia.org/wiki/France_at_the_2008_Summer_Olympics) | 7 | 16 | 18 | **41** | |

Tables 1.1 and 1.2 differ only by how medals are ranked: by the number of gold medals or by the total medals. The data in these tables is identical; only the presentation has changed. Yet this small choice has several different consequences, including whether causal readers will infer that China or the USA has “won” the Olympics. Note also, that South Korea drops off the list when rankings are done by total medals rather than golds and Germany and Australia switch places on the list.

It is easy to see why U.S. news sources prefer Table 1.2. Since the U.S. has so many contestants in the Olympics, rankings that favor total medals tend to show the U.S. in good light. Thus, the audience for what at first seems to be relatively straightforward fact influences how the data is presented and the conclusions readers will draw.

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| **Exercise 1.2: Statistics on depression.**  Consider the following statistic: "*21.3% of women and 12.7% of men have experienced depression in their lifetime.*" By performing some basic mathematical operations, we can rewrite this statistic as:   1. Over one in five women and one in eight men have experienced depression in their lifetimes. 2. Women are 68% more likely than men to experience depression in their lifetime. 3. Approximately six of every ten depressed individuals is a woman. 4. 17.1% of individuals have experienced depression in their lifetime. 5. Over 75% of women never experience significant depression in their lifetime.   Since we don’t know the context, use the triad of purpose-audience-trust to describe each of these representations. What seems to be the purpose and audience of each? Are any of them more alarming or reassuring than others? Do any make you question your trust in the writer? |

**Lies, Damn Lies and Statistics**

People don’t blame words for lying

Can distort a video clip

**Your Own vs. Others’ Data (Planned vs. Found Data)**

Sometimes the data that you work with will be planned for a specific purpose. You will have a hypothesis and then plan a study collecting data to test that hypothesis. Sometimes you will have broader, less well-defined questions, such as *how do women and men communicate differently* or *what are the bottlenecks in our organization*, and you will collect data to answer those questions. And sometimes you will skip the data collection process and instead work with information that has already been gathered—and sometimes already analyzed—by other people.

An example of how we might use data that has already been gathered and analyzed can be seen in the Olympic medal data in Tables 1.1 and 1.2. This data has been gathered and published by the Olympic committee and numerous new sources, but this does not mean that the analysis is complete. For instance, in response to the controversy over how to report the medal counts from the 2008 Olympics, a New York Times reporter developed a point system.

**Descriptive vs. Quantitative Data**

Data does not refer simply to numerical data, such as we see in the Challenge Memo in figure 1.1 or in the depression statistics in Figure 1.2. Data also includes observations, quotations, interviews, reflections, and texts. Although such forms of data can often be represented numerically—for instance we can count the number of times we observe a certain behavior or the proportion of interview participants who respond in a particular way to a question—often times, we aim to **describe** rather than **quantify** these types of data.

**Descriptive data** uses case studies and descriptions of individual people, events, or locations and discusses them in ways that are not easily reduced to a number. **Quantitative data** involves collecting concrete measurements on a scale—such as temperature, speed, or size—or else aggregating individual attributes—such as repair records, behaviors, or attitudes—so that they can be combined, compared, and analyzed as specific data points.

Those who primarily quantify data often dismiss descriptive data as “soft” or “anecdotal” since it looks primarily at individual cases that cannot be put to the power of **statistical significance tests.** There are many cases where poor decisions have been made by relying on individual anecdotes or experience rather than examining trends across broader samples.

**Statistical significance tests** are procedures used to help rule out the possibility that a given result or finding could have occurred by chance alone. A result that statistical tests determine is unlikely to have occurred by random chance is termed **statistically significant.** For this reasons it is recommended to avoid using the word “significant” when talking about data, unless you will be reporting the results of statistical tests.

On the other hand, those who work primarily with descriptive data frequently dismiss quantitative data as “reductive” or broad since we lose individual variation and nuance when we aggregate a large number of data points. There are many instances where individuals have been mislabeled because their behaviors or attributes are lumped into an average.

The truth is, we need both descriptive and quantitative data to make informed decisions. Quantitative data allows us to see trends and make concrete comparisons that can be supported by statistical tests. Descriptive data provides information that can make us question or challenge the trends we observe and gives us a way to discuss qualities that are not immediately measureable.

Nearly all fields and professions rely on both types of data. The two types of data complement and supplement one another and are not always as easy to tell apart as we might first assume. A good technical communicator needs to be able to discuss both types of data and show the benefits of each.

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| **Exercise 1.3: Descriptive and Quantifiable Data**  Most situations in which we work with data involve both descriptive and quantifiable data. For the following scenarios, identify different kinds of both descriptive and quantitative data that might be analyzed to discuss the situation:   1. A doctor is asked to examine a patient admitted to the Emergency Room with symptoms that are difficult to diagnose. 2. An engineer is asked to write an incident report of an accident at a manufacturing plant. 3. An instructor includes student evaluations of his teaching in a file nominating him for a teaching award. 4. A technology entrepreneur conducts a competitive market analysis trying to convince investors that there is a market share for her new GPS device. (A market analysis tries to show both that there is interest in a new product and that there is a need for the product not already met by the competition). |

**Quantitative Literacy and this Book**

The majority of quantitative examples in this book assume knowledge of basic summary statistics, which include averages, percentages, and ratios. These functions are considered to be eighth grade math. Occasionally, a more advanced concept will be introduced. For students who know the math behind these advanced concepts, this book will discuss the most effective ways to present these statistics for non-technical or scientific audiences. For those who are unfamiliar with these concepts, this book will explain how to read and understand statistical information—without going into the details of how to perform the calculations.

In other words, this book assumes basic quantitative literacy—or the familiarity with numbers a person in our society needs in order to be considered fully literate. Advanced concepts will occasionally be presented, but their meaning for the average, non-mathematical citizen will be discussed.

If you are worried you may not have basic quantitative literacy (and a surprising number of high school and college graduates have trouble with some basic mathematical concepts), you should search for a tutorial on the internet and practice until calculating percentages, averages, and ratios is as comfortable as reading a scientific text written at an eighth or ninth grade level.

What distinguishes the way we talk about summary statistics and other quantitative concepts in this book from a math text is that this book focuses on how to integrate numbers and words. It teaches you to make an argument with numbers and helps you critique and take apart quantitative arguments made by others. Such an ability to think about words and numbers *together*—and not as separate, isolated entities as they are typically treated in schools—is a necessary skill to survive in the twenty-first century.

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