Living with Complexity

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Things That Make Us Smart, 1993

The Invisible Computer: Why Good Products Can Fail, the Personal Computer Is So Complex, and Information Appliances Are the Answer, 1998

Emotional Design: Why We Love (or Hate) Everyday Things, 2004

The Design of Future Things, 2007

CD-ROM

First Person: Donald A. Norman. Defending Human Attributes in the Age of the Machine, 1994. Santa Monica, CA: Vanguard.

Figure 1.1
Messy desks by organized people. Some people's desks reflect the complexity of their lives. But to the person who owns the desk, everything is in its place, there is order and structure. Photograph of Al Gore by Steve Pyke. © Steve Pyke/Contour by Getty Images.

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Living with Complexity
Why Complexity Is Necessary

The guiding motto in the life of every natural philosopher should be, Seek simplicity and distrust it.
—Alfred North Whitehead (1920/1990)

The person in figure 1.1 sits unperturbed by the apparent chaos of his desk. How does he cope with all that complexity? I've never spoken with the person in the picture, Al Gore, former Vice President of the United States and winner of the Nobel Prize for his work on the environment; but I have talked with and studied other people with similar-looking desks, and they explain that there is order and structure to the apparent complexity. It's easy to test: if I ask them for something, they know just where to go, and the item is retrieved oftentimes much faster than from someone who keeps a neat and orderly workplace. The major problem these people face is that others are continually trying to help them, and their biggest fear is that one day they will return to their office and discover someone has cleaned up all the piles and put things into their "proper" places. Do that, and the underlying order is lost: "Please don't try to clean up my desk," they beg, "because if you do, it will make it impossible for me to find anything."

My own desk is not nearly as messy as Al Gore's, but it is piled high with papers, technical and scientific magazines, and just plain "stuff," chaotic in appearance, but exhibiting an underlying structure that only I am privy to.

How do people cope with such apparent disorder? The answer lies in the phrase "underlying structure." My desk looks chaotic and incomprehensible to anyone who is unaware of the reasoning behind the many disparate piles. Once the structure is revealed and understood, the complexity fades away. So it is with our technology. Does the cockpit of a modern jet airliner (figure 1.2) look complex? To the average person, yes, but not to the pilots. To them, the instruments are all logical, sensible, and nicely organized into meaningful groups.

"Why is our technology so complex?" people continually ask me. "Why can't things be simple?" Why? Because life is complex. The airplane cockpit is not complex because the engineers and designers took some perverse pleasure in making it that way. No: it is complex because all that stuff is required to control the plane safely, navigate the airline routes with accuracy, keep to the schedule while making the flight comfortable for the passengers, and be able to cope with whatever mishap might occur en route.

I distinguish between *complexity* and *complicated*. I use the word "complexity" to describe a state of the world. The word "complicated" describes a state of mind. The dictionary definition for "complexity" suggests things with many intricate and interrelated parts, which is just how I use the term. The definition for "complicated" includes as a secondary meaning "confusing," which is what I am concerned with in my definition of that word. I use the word "complex" to describe the state of the world, the

Figure 1.2
Appropriate complexity. To the average person, the cockpit of a modern jet airplane is incredibly complicated and confusing. Not for the pilots: to them, the instruments are all logical, sensible, and nicely organized into meaningful groups. This is the flight deck of a Boeing 787.

tasks we do, and the tools we use to deal with them. I use the word "complicated" or "confused" to describe the psychological state of a person in attempting to understand, use, or interact with something in the world. Princeton University's WordNet program makes this point by suggesting that "complicated" means "puzzling complexity."

Complexity is part of the world, but it shouldn't be puzzling: we can accept it if we believe that this is the way things must be. Just as the owner of a cluttered desk sees order in its structure, we will see order and reason in complexity once we come to understand the underlying principles. But when that complexity is random and arbitrary, then we have reason to be annoyed.

Modern technology can be complex, but complexity by itself is neither good nor bad: it is confusion that is bad. Forget the complaints against complexity; instead, complain about confusion. We should complain about anything that makes us feel helpless, powerless in the face of mysterious forces that take away control and understanding.

My challenge is to explore the nature of complexity, to relish its depth, richness, and beauty at the same time that I fight against unnecessary complications, the arbitrary, capricious nature of much of our technology. Bad design has no excuse. Good design can help tame the complexity, not by making things less complex—for the complexity is required—but by managing the complexity.

The keys to coping with complexity are to be found in two aspects of understanding. First is the design of the thing itself that determines its understandability. Does it have an underlying logic, a foundation that, once mastered, makes everything fall into place? Second is our own set of abilities and skills: Have we taken the time and effort to understand and master the structure? Understandability and understanding: two critical keys to mastery.

The major issue is understanding: things we understand are no longer complicated, no longer confusing. The airplane cockpit of figure 1.2 looks complex but is understandable. It reflects the required complexity of a highly technological device, the modern commercial jet aircraft, tamed through three things: intelligent organization, excellent modularization and structure, and the training of the pilot.

Almost Everything Artificial Is Technology

Tech•nol•o•gy (noun): New stuff that doesn't work very well or that works in mysterious, unknown ways.

Technology: the application of scientific knowledge to the practical aims of human life or, as it is sometimes phrased, to the change and manipulation of the human environment.

The definition of technology as "New stuff that doesn't work very well" is mine. The more standard definition as "the application of scientific knowledge" comes from the *Encyclopaedia Britannica*. Most people seem to hold the first definition, so that commonplace things such as salt and pepper shakers, paper and pencil, or even the home telephone or radio are not considered technologies. But yes, they are indeed technologies, and as I discuss in chapter 3, even the simplest of technologies can reveal hidden complexities. Simple everyday things can be confusing if we encounter them in large numbers where each thing, though simple by itself, comes in many different varieties and forms, each requiring a different principle of operation: keeping track of which item requires what particular operation is indeed complicated and confusing. Similarly, some apparently simple things are complicated because to use them properly requires knowledge of culture and customs as well as the behavior of others.

Why has the term "technology" come to refer primarily to items that cause confusion and difficulty? Why so much difficulty with machines? The problem lies in the interaction of the complexities of technologies with the complexities of life. Difficulties arise when there are conflicts between the principles, demands, and operation of technology with the tasks that we are accustomed to doing and with the habits and styles of human behavior and social interaction in general. As our technologies have matured, especially as everyday technologies have come to combine sophisticated computer processing and worldwide communication networks, we are embarking upon complex interactions.

Machines have rules they follow. They are designed and programmed by people, mostly engineers and programmers, with logic and precision. As a result, they are often designed by technically trained people who are far more concerned about the welfare of their machines than the welfare of the people who will use them. The logic of the machines is imposed on people, human beings who do not work by the same rules of logic. As a result, we have species clash, for we are two different species, people and technology. We are created differently, we follow different laws of nature, and each of us works according to invisible principles,

How Even Simple Things Can Become Frustrating and Complicated

Want an example of an unnecessarily complicated, frustrating device? Take my piano. The controls of the Roland piano shown in figure 1.3 are perplexing beyond belief.

The piano settings are important, for they allow the player (my wife) to make the piano sound precisely in the desired way, in our case, like a concert grand piano for playing classical music. It takes quite a while to adjust everything just right, but that's OK because there are many subtleties to be controlled, and each one seems reasonable and logical. But after all that work, it is only natural that we would want to be able to save the results so that they are always present whenever we turn on the power and start playing.

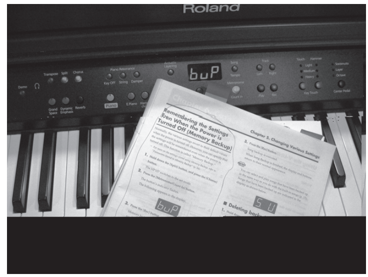
The concept of saving the settings for a device is simple enough. It is a frequent operation for any device that has numerous adjustments and settings. How are the users of this piano expected to save their settings? Here is the text from the manual (shown in figure 1.3):

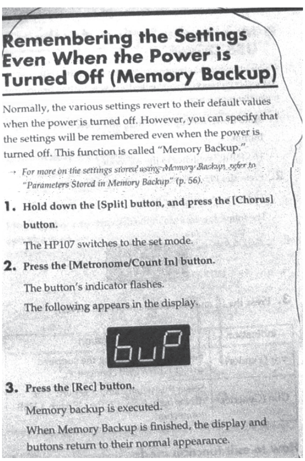
1. Hold down the [Split] button, and press the [Chorus] button.
2. Press the [Metronome/Count In] button (buP should appear in the display)
3. Press the [Rec] button.

Even though my wife and I have saved the settings on numerous occasions, we can never remember the sequence and must always dig out the manual and try to do the operations. The steps are so arbitrary and unnatural that each time I have to do this, the first attempt always fails, even with the manual open in front of me.

This is an expensive piano, with a great mechanical feel to the keys and excellent acoustics mirroring the rich subtleties of the best acoustic pianos. But the company completely neglected the controls for the piano. They used a cheap, inelegant display (see the poor-quality of the display letters in figure 1.3) and although there are dedicated buttons for controlling the musical sounds, there is no attention paid to other aspects of the piano setup. In other words, the piano controls were an afterthought, with no attention paid to the needs of the customer—a violent contradiction to the care and concern that went into designing the musical quality of the piano.

Usually, when I see bad design, I try to imagine what forces were involved to cause such a poor result. In this particular case, I fail. The reasons are unfathomable. Event the Owner's Manual is unintelligible. This is a design problem, and good designers can think of many elegant solutions to prevent accidental loss of the desired settings. The major cause of complicated, confusing, frustrating systems is not complexity: It is poor design.





Remembering the Settings Even When the Power is Turned Off (Memory Backup)

Normally, the various settings revert to their default values when the power is turned off. However, you can specify that the settings will be remembered even when the power is turned off. This function is called "Memory Backup."

→ *For more on the settings stored using Memory Backup, refer to "Parameters Stored in Memory Backup" (p. 56).*

1. **Hold down the [Split] button, and press the [Chorus] button.**
   The HP107 switches to the set mode.
2. **Press the [Metronome/Count In] button.**
   The button's indicator flashes.
   The following appears in the display.
   buP
3. **Press the [Rec] button.**
   Memory backup is executed.
   When Memory Backup is finished, the display and buttons return to their normal appearance.

From the manual shown in the left photo: How to set the piano to remember the settings.

Hold down the [Split] button, and press the [Chorus] button

Press the [Metronome/Count In] button

(buP should appear in the display)

Press the [Rec] button.

Figure 1.3
Stupid complexity. The Roland piano is unnecessarily complicated. It's a wonderful piano, with great attention paid to the proper feel of the keys and superb rendering of the sound. But the operation of the digital controls defies comprehension. It is an expensive piano, with a really cheap display, hence the weird letters that appear. Great musicians worked on the sounds of the notes and the feel of the keyboard. Inept designers worked on the controls.

hidden from the other, principles that harbor unspoken conventions and assumptions.

When complexity is unavoidable, when it mirrors the complexity of the world or of the tasks that are being done, then it is excusable, understandable, and learnable. But when things are complicated, when the complexity is the result of poor design with completely arbitrary steps, with no apparent reason, then the result is perplexing, confusing, and frustrating. Poor design leads to the emotional distress we have come to associate with modern technology. Good design can provide a desirable, pleasurable sense of empowerment.

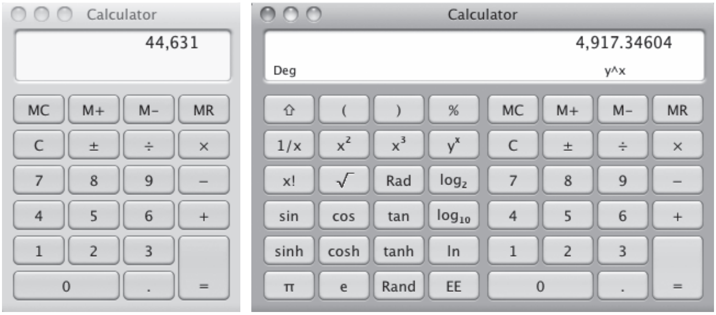
There are many cries for simplicity in our lives, simplicity in the activities we pursue, the possessions we own, and especially in the technologies that we use. "Why are there so many buttons, so many controls?" people plead. "Give us fewer buttons, fewer controls, fewer features," they say. "Why can't we have a cell phone that just makes phone calls: no more, no less?" Invariably, the demand for simplicity is illustrated with wonderfully simple devices and things, simple appliances, hand tools, or household items, all with the intent of demonstrating that simplicity is indeed possible.

In attempting to reduce the frustrations caused by the complicated nature of much of today's technology, many solutions miss the point. It is no great trick to take a simple situation and devise a simple solution. The real problem is that we truly need to have complexity in our lives. We seek rich, satisfying lives, and richness goes along with complexity. Our favorite songs, stories, games, and books are rich, satisfying, and complex. We need complexity even while we crave simplicity.

The difficulty with the cry for simplicity is that many of our activities are not simple. A cell phone, for example, is expected to be able to be turned on and off (that's one control), to make and receive phone calls and then to be able to end them—that's another two controls. If we wish to dial a telephone number we need buttons for the ten digits. But even that is not enough: it's useful to store a list of frequently called people and to keep a list of who has called the phone and who has been called. We keep adding desirable actions: take photographs, play music, listen to a call with loudspeaker or earphones, and send text messages. We want to be able to do all of these things, yet we want the device to be simple. The real challenge is to tame the complexity that life requires.

Real activities are incredibly intricate with numerous components, the requirement for flexible execution, and the need for numerous alternatives. So how do we manage that complexity? Suppose a simple, small device has twenty-five buttons. Worse, suppose it has fifty. That just has to be complicated, right? Wrong.

Later, in chapters 7 and 8, I discuss the rules of design; but for now take a look at the calculators of figure 1.4. Because the many buttons are organized into logically sensible patterns, the calculator is not perceived to be particularly complex: ten number keys plus a decimal point, five arithmetic operations, a key to reverse the sign of a number, and a clear key, and four memory keys. And three buttons at the very top, dealing with the computer display. Even if the memory keys and the change sign key are novel and not understood, the calculator as a whole is sufficiently well understood that they can simply be ignored. Similarly, the scientific calculator with almost fifty keys is sufficiently well organized



(a) (b)

Figure 1.4

Many buttons do not necessarily lead to confusion. The calculator in figure 1.4a has twenty-five buttons (including the three circular ones at the top left that control the computer window for the calculator). But because they are organized into logical groups, most people find the calculator to be simple and understandable. Similarly, the scientific calculator in figure 1.4b with forty-nine buttons (and a display) is readily understood, even by people who have no idea what the labels “sinh” “Rand,” and “y^x” mean: they can simply be ignored.

that it too can be used even if not all the keys are understood. In this example, familiarity and organization are the two secrets of simplification.

Simplification is as much in the mind as it is in the device. Just imagine that the keys had been randomly arranged: the same calculator that was once easy to use then becomes quite difficult and confusing. Organizational structure makes the difference.

Complex Things Can Be Enjoyable

The world is complex. Look at the flags in figure 1.5. Does it make sense that two flags just across the street from one another should blow in opposite directions? The flags flying in opposite directions reflect the invisible complexity of nature. Note that observing the flags does not lead to irritation or annoyance so much as amusement: “Maybe we shouldn’t go out today, or if we do, watch out for the wind.” That is the way nature is: wind can sometimes move in mysterious, complex ways.

Some complexity is desirable. When things are too simple, they are also viewed as dull and uneventful. Psychologists have demonstrated that people prefer a middle level of complexity: too simple and we are bored, too complex and we are confused. Moreover, the ideal level of complexity is a moving target, because the more expert we become at any subject, the more complexity we prefer. This holds true whether the subject is music or art, detective stories or historical novels, hobbies or movies.

Sometimes the complexity is unexpected, but necessary, as in sports or law, where the ability of people to figure out ways around

Figure 1.5
Even nature is complex. Two flags, just across the street from one another, but blowing in opposite directions. Why? Just a typical windy day in Evanston, Illinois, just north of Chicago (also known as "the windy city"). (The photograph is authentic, taken from the window of my apartment.)

rules requires yet more rules. Today, the laws are both numerous and imprecise, so that not even our most powerful computers can master them. In sports, professional referees must sometimes huddle or call on others to determine a ruling. The American game of baseball, for example, is a relatively simple game, but the rulebook is over 200 pages long: the simple listing of baseball terms with abbreviated definitions takes thirteen pages. The same phenomenon is true of all major sports. The official rulebook for soccer from the International Football Association Board is over seventy pages long with a forty-four-page "Question and Answer" section plus a 300-page guidebook for officials. Their convenient downloadable "laws of the game" has 138 pages.

Let's take one example from baseball. The infield fly provides a good example of baseball's complexity. For readers who do not follow sports, or to whom baseball is foreign, the following text may seem inscrutably mystifying, which is precisely the point. Whatever your favorite sport, hobby, or profession, experts relish the details while others scratch their heads, amazed that human adults would spend so much time and energy on such matters. I guarantee that whatever your favorite pastime, there will be customs or rules just as arcane, just as inscrutable as that for baseball's infield fly rule.

The point of the rule is this. If the batter hits a fly ball into the infield and a member of the defending team catches it before it hits the ground, all offensive players who were running around the bases must return to the base they started from. Moreover, they are allowed to return safely. But that rule provides an interesting opportunity: Suppose the ballplayer failed to catch the ball: then it would be permissible for the player to quickly pick up the ball and

or of a sport, are necessary to define the parameters of permissible behavior. Our behavior is complex and sometimes perverse: our rulebooks and laws mirror that complexity.

Even where complexity is not required, we sometimes seek it out. Look at the coffeemaker of figure 1.6. Is this complexity necessary? Actually, the making of coffee is a wonderful example of the trade-offs between simplicity and complexity, convenience and taste, ease versus the pleasure of drawn-out rituals.

Coffee and tea start off as simple beans or leaves, which must be dried or roasted, ground, and infused with water to produce the end result. In principle, it should be easy to make a cup of coffee or tea. Simply let the ground coffee beans or tea leaves seep in hot water for a while, then separate the grounds and tea leaves from the brew and drink. But to the coffee or tea connoisseur, the quest for the perfect taste is long-standing. What beans? What tea leaves? What temperature water and for how long? And what is the proper ratio of water to leaves or coffee?

The quest for the perfect coffee or tea maker has been around as long as the drinks themselves. Tea ceremonies are particularly complex, sometimes requiring years of study to master the intricacies. For both tea and coffee, there has been a continuing battle between those who seek convenience and those who seek perfection. Do you want the ritual of tea or coffee making, followed by luxurious enjoyment, or do you simply want to have the drink immediately, without fuss or bother? At times, we might prefer the complexity of the ceremony and the complex subtleties of the taste, while at other times, we put ease and simplicity over ceremony and ritual. The preparation of food is one case where, in the trade-off between simplicity and complexity, simplicity does not always win.

Figure 1.6
Delightful complexity. The Balancing Siphon Coffee Maker by Royal Coffee Makers. Does the coffeemaker seem overwhelmingly complex? Yes, and that is just the point: the delightful visual complexity is one of the attractions.

The quest for the perfect coffeemaker that will provide the perfect flavor with the least amount of effort is worthy of study in its own right. The options vary from the simple to the elaborate. The simplest is probably throwing cracked or ground beans into a pot of water and letting them boil a few times (three is the magic number in many countries). The most elaborate is to use expensive machines that automatically grind the beans, tamp them, heat the water, make the coffee, and dispose of the grounds. The variety of automatic coffeemakers continues to increase, from automatic drip coffee machines to today's favorite new coffee pod method. Using one prepackaged pod per cup, it provides a single cup of coffee with minimum wait and cleanup required.

An extreme case that favors complexity is the wonderful vacuum coffeemaker shown in figure 1.6. Put the water in the right-hand container, the coffee in the left. Light the fire under the right-hand container and when the water boils, the resulting air pressure forces the water into the left-hand container, where the water mixes with the coffee. The left-hand side is now heavier than the right-hand side, which causes a cover to drop over the flame, allowing the right-hand side to cool, decreasing its pressure. The coffeemaker's manual says this creates a vacuum on the right that sucks the coffee back into the container, straining the beans out as it makes its passage. I have no idea how good the coffee is, but the machine itself and the ritual are clearly the major components of the pleasure of the machine.

Why such a complex routine to make a simple cup of coffee? Rituals invariably add complexity to our lives, but in turn, they provide meaning and a sense of membership in a culture. For the coffee-lover, the intricate ritual of coffee preparation adds fun and pleasure to life. If cost and time were irrelevant we might always prefer freshly prepared food to canned and frozen food, freshly ground and brewed coffee or whole-leaf tea to instant coffee or teabags. Ultimately most of us choose which method to use depending on time factors and the importance of each event in its social context.

All cultures have rituals for food preparation and eating. When we eat we follow societal conventions: which utensils to use and for what? Who eats first, or last? Who serves or pours for whom? It is all covered by ritual. Consider these three alternatives: (A) a meal cooked by a chef who hand-chopped fresh food, sautéed the portions that needed sautéing, and spent thirty minutes preparing the food to your taste; (B) the same as (A) except that you are the chef; (C) food quickly prepared by defrosting a frozen package in a microwave oven. Which alternative would you prefer? Answer: it all depends. Life is always a complex mixture of trade-offs, in this case including time and effort, cost, taste, the pleasure of creating something, and the needs of the day.

Common Aspects of Life That Require Months of Study

One way to measure complexity is by the amount of time required to learn the item. The surprise is the number of activities that we take for granted; even activities that we like to call easy and "intuitive" are actually complex, arbitrary, and difficult to master. Some difficult things are a result of the complexity of nature and the world. Thus, the complexity of farming results from the complex intermix of the biological needs of plants, the vagaries of weather and its yearly cycle, and the care and feeding of farm animals. Food preparation is complex because of the needs to transform the raw material, whether animal, vegetable, or mineral, into a form that is digestible and palatable. On top of these natural needs, people have imposed social requirements such as the elaborate rituals that accompany the preparation and consumption of food. The rules that establish what kind of behavior is proper and appropriate while dining—table manners—may be arbitrarily complex and even meaningless, but society demands that they be learned and followed. Even people who believe that they ignore the standards in fact have their own internal rituals to follow.

Society has adapted to many arbitrarily complex systems so well that adults scarcely pay any attention to their complexities and difficulties, for they have forgotten the long period of study required to master them. Two complex systems that are both complex and confusingly complicated are time specification and alphabets.

The human relationship with time has a very long history. Farming and hunting follow yearly cycles, which led to the development of calendars and timekeeping, regulated mostly by priests. The industrial revolution created factories that required multiple people to work together, both in the same location and at the same time, so the clock became an important method of controlling behavior: when to wake, eat, and pray; when to report to work, when to take a break, and when to quit. The clock, and therefore timekeeping, regulated society, even though the clock itself is an arbitrary mechanical device, not well suited to human needs.

Once upon a time, the hours of the day were specified according to human needs, with the daylight period broken up into twelve hours. Noon was the start of the sixth hour. In northern climates, the period of daylight is far longer in summer than in winter, but because the hour was defined as one-twelfth of the period between sunrise and sunset, a summer hour was much longer than a winter one. Although this method of timekeeping has been replaced with the mechanical consistency of pendulums, astronomical measurements, and atomic vibrations, the division of the day into two periods of twelve hours remains. During the French revolution at the end of the eighteenth century an attempt was made to redefine the units of time in a more sensible, decimal format. Obviously, the attempt failed.

Time is indicated by clocks with two similar-looking rotating hands, one indicating units of twelve, the other units of sixty. Many people resist the simplification of timepieces to easy-to-understand decimal displays, instead preferring the rotating analog displays that take children months to master and still give rise to interpretation errors. (The claim is that the "analog" hand allows one to make a ready estimate of time past or remaining. Try explaining that to a child struggling to learn the system.) The way we specify time is complex and confusing, but society has learned to accept it.

Alphabets form another set of arbitrary complexity. Language naturally evolved through speech and gesture. The invention of writing caused the different cultures of the world to grapple with the way by which sounds might be represented through written marks. The result is a wide variety of methods, not all of which are well matched to the sound systems of the language.

Some languages have an alphabet, with each symbol supposedly representing a sound. Some have syllabaries, where a symbol represents a syllable, usually a consonant-vowel pairing. Some languages don't have either alphabet or syllabary, just a unique ideogram for each word, so learning to read involves memorizing each character and its pronunciation, a process that continues over a lifetime: Chinese is the main such example. Japanese uses both syllabaries and ideograms, compounding the problem by having two quite different-looking syllabaries, although with the same sound patterns. Learning Japanese requires learning two syllabaries (katakana and hiragana) plus Chinese ideograms (kanji), as well as the Roman alphabet, which is used for some words and situations.

All readers of a language have had to master its writing system, but most adults forget how difficult that task was. Not only do the pronunciations for each symbol have to be mastered, but the pronunciation often varies with the context. Even the shapes of letters can be written in different ways depending on whether it is upper or lowercase, handwritten (cursive) or printed, or if it is at the start, middle, or ending of a word. Some languages use the vowel symbols only for children or people learning the language, leaving them out of adult texts. Writing systems for the different languages of the world are amazingly complex.

The tension between power and ease of learning is not easily overcome. In some languages, the relationship between the character and the sound is direct and straightforward. In others, the relationship seems bizarre and arbitrary, with English being probably the worst example of arbitrary spelling and pronunciation.

Some languages have a carefully designed alphabet. For example, the Hangul alphabet of Korea was carefully designed in the fifteenth century by the Emperor and a committee of linguists (but continually refined even during the mid-twentieth century) to have fourteen symbols for the consonants of the language plus ten symbols for the vowels. Words are formed by arranging the characters into blocks, each comprised of three or four consonant-vowel-consonant groupings. Although the result looks a bit like a Chinese character, it is composed of alphabetic symbols, which means that the pronunciation of new words can be figured out, something that is not true with Chinese characters. Native Korean speakers perceive this to be so easy and elegant that they claim the alphabet can be mastered in fifteen minutes. One authoritative book by a linguist is entitled "You can learn the Korean alphabet in one morning." These claims are highly exaggerated.

Example: The sounds corresponding to the six English letters of the word "Hangul" are represented by the six Hangul characters "ㅎ," "ㅏ," "ㄴ," "ㄱ," "ㅡ," and "ㄹ." These characters are written in two blocks of three characters each as "한글."

I write this paragraph while I am in Daejeon, South Korea, where I have been struggling for weeks to learn Hangul, the Korean alphabet. Other non-Koreans confirm that this is how long it took them. Why is it so difficult? Yes, the alphabet is designed elegantly. But all languages have their subtleties of pronunciation and it is difficult for a writing system to capture all of the spoken sounds. English has twenty-six letters in its alphabet, but the rules of English spelling and pronunciation are incredibly complex: even native speakers make mistakes. The Korean alphabet, in addition to its ten vowels and fourteen consonants, has eleven additional vowel symbols derived from combinations of the basic vowels, five double consonants, which have their own rules, and then eleven more combined consonant rules.

In all, there are fifty-one different symbols to be learned, and although scholars insist the shapes are not arbitrary because the letter shapes are said to indicate the proper shape of the mouth and tongue in creating the sounds or phonemes, in practice this relationship is so subtle and abstract that for me at least, it plays no role in learning. Hard to learn? Complex? Yup.

Don't blame Korea for this complexity: it really does have one of the most logical and elegant of all alphabets. Blame the world. Languages have evolved over thousands of years and all have developed shortcuts, borrowed forms, special cases of grammar and pronunciation. No simple alphabet or syllabary can completely capture its inherent complexity.

This is the way of all human languages. Wonderfully expressive, wonderfully powerful. The invention of writing has enhanced our lives immensely. Writing allows knowledge, thoughts, stories, and poetry to be saved for others. It allows the dissemination of knowledge across space and time. It is the invention of artifacts such as writing that makes us smart: it is things that make us smart, things including inventions such as writing and reading. But the written marks on paper are so very different from the spoken sounds of a language that the apparent contradictions and complexities are inevitable. The spoken language is natural, learnable by anyone. The written language is arbitrary and capricious, difficult to learn, with a surprisingly large number of the world's population unable to master it.

The way we represent music has far-reaching historical roots, but that doesn't mean it is easy. For most instruments, musical notes are depicted by ovals located on staves, each staff having five horizontal lines, allowing notes to be placed below and above the staff (sometimes by adding short, temporary horizontal lines that act as extensions of the five fixed ones of the staff), with the notes being placed either on lines or between them. The lines and spaces do not allow for all the notes used in music, so other symbols, sharps (♯) and flats (♭), need to be used as well. Adding to the complexity, the notes on a staff are determined by a particular clef symbol. There are four clefs in wide use: treble, bass, alto, and tenor, so the very same set of ovals and lines mean different notes in the different clefs. An oval on the bottom line of the staff has a different meaning in each clef: It is read as an E in treble clef, a G in bass clef, an F in alto clef, and a D in tenor clef. Piano players usually use two clefs, bass and treble, which means that they have to read two staves simultaneously, with different rules for each. Organ music uses a grand staff comprised of three staves, one for each hand and one for the foot pedals.: usually top staff is treble clef, bottom staff is bass clef, and middle jumps back and forth. In design, when the same symbol or operation means different things depending on the context, it is called a "modal" display, and it is a well-known source of confusion and error.

The confusion in reading music is not necessary. After a little bit of tinkering, I devised a notational scheme in which every clef represents precisely one octave, so an oval always means the same thing, regardless of which clef it appears in. But then a little bit of sleuthing on the Internet revealed that I had joined a long list of innovators who have attempted to overcome the deficiencies of the scale system. The influential twentieth-century composer Arnold Schoenberg, writing almost a century ago (1924), said, "The need for a new notation, or a radical improvement of the old, is greater than it seems, and the number of ingenious minds that have tackled the problem is greater than one might think."

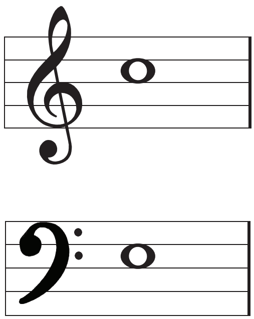
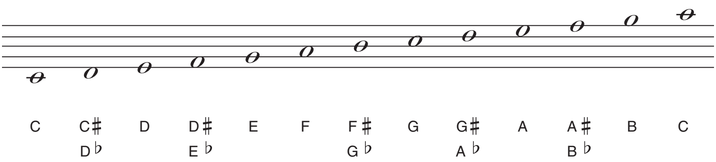


Figure 1.7
The treble and bass clefs. Illustrating the modal nature of this notation that adds to the confusion in learning: the oval of the treble clef (upper staff) indicates the musical note C, whereas the same symbol on the bass clef (lower staff) indicates an E.

I soon discovered a notational system superior to mine that eliminated the need for all those sharps and flats and other confusions brought about by keys. This was a chromatic staff, using five lines just as is used now, but assigning every note to its own position. This gets rid of the need to mark sharps, flats, or naturals, or for that matter even to indicate the key of music, except to inform the player. Thus, the bottom line of the staff represents D, but the space above that is D♯, the next line E, the space above that F, and then the next line F♯ (see figure 1.8).

Could we ever switch to this or any of the many other rational systems? Unlikely: tradition is difficult to overcome.

Musical instruments come in a wide variety of shapes, sizes, and forms. Most have a long history, sometimes thousands of



Chromatic scale on a five-line chromatic staff

Figure 1.8
Chromatic scale notation. A superior rendering of the musical staff in which sharps and flats need no longer be used, scale markings are redundant (but still useful), but most important of all, because each staff represents exactly one octave, every staff, whether higher or lower in the scale, always represents notes the same way: D, for example, is always the note on the bottom line, regardless of the octave in which it is to be played. From The Music Notation Project, http://musicnotation.org/.

years, and their basic structure derives in part from the accidental discoveries of early musicians, in part from the properties of the physics of vibrating strings, columns of air, membranes, and reeds. Very little attention has been paid to the ergonomics of the instruments. As a result, they often require awkward body positions, such as the contortion of the left hand required to play the violin and related stringed instruments, and sometimes exert great strain: look at the bulging cheeks of brass players, or the calluses on fingers tips of string players. Numerous musicians, especially those who use keyboards or stringed instruments, have had to end their careers because of repetitive stress injuries from playing. Many professional musicians have suffered severe hearing losses because they must endure very high sound levels for extended periods. I am convinced that if the instruments were introduced today and forced to undergo ergonomic review for health and safety, they would fail. The makers of computer keyboards, a mild device compared to many musical instruments, have been repeatedly sued in the U.S. courts for injuries to the hands and wrists.

Musical instruments are not easy to master. Even the most simple-looking can take years. The piano, for example, is relatively straightforward to understand, but incredibly difficult to master. The learning time is measured in years. Note that there are two parts to learning an instrument. One is the physical mastering of the mechanics itself: how to hold the hands, posture, and breathing. Many instruments require demanding physical exertion or special blowing techniques. Some require different rhythms in each hand simultaneously, and some require use of both hands and feet simultaneously (harp, piano, organ, percussion). But that, in many ways, is the easy part. The hard part is mastering the music, understanding the composer's and conductor's intentions, and playing in harmony with the other players. In jazz or rock music, there may be no printed score, so the performer has to improvise appropriately. These skills require a lifetime of practice.

Even the everyday activity of automobile driving, which seems easy once mastered, is complex enough that it takes weeks of instruction and then months to develop skilled performance. Remember when you first learned to drive? Everything seemed to be happening so quickly, with simultaneous actions required of each hand and foot, while watching out for cars behind, to the sides, and for objects in front, plus reading and obeying traffic signs and lights that were located at unknown places along the road: it seemed impossible. After a few years of driving, it feels so simple and easy that people eat food, put on makeup, pick up items from the floor, and do all sorts of activities while driving. The simplicity is deceiving. During normal driving, the skilled driver has lots of free time: if anything, driving is boring. But suddenly, without warning, a dangerous situation can appear. The result is that every year, tens of millions of people across the world are injured in automobile accidents.

Is driving simple or complex? Understandable or complicated? Answer: it all depends on the driver and the situation.

Do we dislike the fact that learning to read and write, play musical instruments, and drive a car are all so complex? Not really. We don't mind complexity when it seems appropriate. Yes, we truly dislike spending an hour learning some arcane, bizarre machinery. But we are willing to spend weeks or years learning other things, where the difficulties and complexity seem appropriate to the tasks: driving a car, learning the multiplication table, and rules of long division. Or learning the alphabet, and, when visiting new countries, learning their alphabets.

Think about learning to play tennis or golf, to draw and paint, or about learning a new craft. Each activity can take months to learn, years to master. I once argued that a minimum of 5,000 hours of study was required to become an expert. That judgment is today thought to be too small a number. Today, the rule of thumb among those who study skilled, expert behavior is that it takes about ten years or 10,000 hours of deliberate practice to reach world-class status. Note that these hours do not mean merely performing or playing: they require deliberate, active practicing, often with the assistance of a teacher or coach. Expert behavior is truly difficult. These tasks have amazing complexity.

I find it interesting that we complain when a new technology requires an hour or two of study. Some people complain if only fifteen minutes of study are required. Yet we do not complain about the huge learning periods required to master the things we have grown up with, such as learning to swim, skate, or ride a bike. Reading, writing, and arithmetic, the fundamentals of education, take years to master. Should we complain about these? No, they are appropriate to the task. When new items are appropriately complex, it is reasonable that they require time and effort to master. Our complaints should be directed toward technologies and services that are unnecessarily complicated, confusing, and without apparent structure.