The Curse of QWERTY

O typewriter! Quit your torture!

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It was boring to type the letters in the upper row of my typewriter keyboard 20 times, then go on to the next row. But it was even more boring to lie in bed and do nothing. So when the chicken pox forced me to stay home from school for two weeks, I used the time to learn touch typing. At age ten I, like millions of Americans each year, memorized the QWERTY keyboard (as it is called from its starting arrangement of letters).

At the time, I didn't wonder about its arbitrariness and never asked myself why our standard keyboard uses the QWERTY arrangement instead of alphabetical order or any other obviously advantageous arrangement. Whatever the original reasons for our adopting QWERTY, however, we now seem firmly committed to it. The typewriter, and its successor the computer, are among the most widely used office machines in the Western world, and keyboard-related repetitive-strain injuries are among our most common industrial accidents.

Commitment is incessantly urged upon us fin de siècle twentieth- century Americans. Commitment to our spouses, our children, and our careers is held to be virtuous; lack of commitment is a common criticism. Yet commitment should be seen as morally neutral. After all, what one is committed to might be either good or bad; commitment to a destructive relationship, an unsatisfying job, or alcoholism deserves no praise. Often, commitment can mean nothing more than an involvement that has outlived its original justification. All of us have at one time or another felt trapped by such a commitment, longing for a happier, though uncertain, state of existence but fearing the short-term pain required to reach it.

Commitment is a big issue not only for us as individuals, but for us as a culture as well. All human societies have many apparently arbitrary practices that persist for centuries or even millennia--writing systems, counting systems, sets of number signs, and calendars, to name just a few examples. At one time there existed alternatives to the system that we eventually adopted. Were some of these alternatives better than others? Did we in fact end up committed to the best

ones? Are our alphabets, decimal counting, Arabic numerals, and Gregorian calendar really superior to Chinese logograms, Babylonian base-60 counting, Roman numerals, and the Mayan calendar?

Those questions are hard to answer for some of these choices-- counting systems, for instance--to which we became committed in the remote past. But the QWERTY keyboard is a modern-day commitment, dating back only to the late nineteenth century, and thus it is one whose history we can reconstruct. We know that QWERTY is the dominant survivor of dozens of keyboard designs that competed during the early years of the typewriter. Hence we can ask, with the expectation of finding an answer, to what advantages does it owe its triumph?

Studies of the consequences of keyboard design were pioneered by the industrial engineers Frank and Lillian Gilbreth, who were made famous by a biography, Cheaper by the Dozen, written by 2 of their 12 children. The Gilbreths sought to decrease worker fatigue and increase the efficiency of many industrial processes (as well as of surgical operations and buttoning a shirt) by time-and-motion studies and slowed-down motion pictures. Applied to keyboard design, such studies showed that typing fatigue, errors, and slow speed depend especially on bad design in allocating letters among keyboard rows, among fingers, and between the left and right hands.

When you prepare to type, you rest your fingers on QWERTY's second-from-the-bottom row, called the home row. Obviously, the more typing you can do without having to move your fingers from the home row, the faster you'll be able to type, the fewer errors you'll make, and the less you'll strain your fingers. Confirming that straightforward prediction, motion-picture studies prove that typing is fastest on the home row and slowest on the bottom row.

You might then naively expect that the QWERTY keyboard was designed so that most typing is done on the home row. You would be wrong. Only 32 percent of strokes are on the home row; most strokes (52 percent) are on the upper row; and a full 16 percent are on the bottom row, which you should be avoiding like the plague. Not more than 100 English words can be typed without leaving the home row. The reason for this disaster is simple: QWERTY perversely puts the most common English letters on other rows. The home row of nine letters includes two of the least used (J and K) but none of the three most frequently used (E, T, and O, which are relegated to the upper row) and only one of the five vowels (A), even though 40 percent of all letters in a typical English text are vowels.

To appreciate the consequences of that misdesigning, just remind yourself of how it feels to type pumpkin or minimum on your QWERTY keyboard. Your fingers must not only reach from the home row to the top or bottom but must at times hurdle completely over the home row, moving directly from top to bottom and back again. Those awkward hurdles and reaches slow you and introduce

typing errors and finger strain. Unfortunately, out of any 100 pairs of consecutive letters in a typical English text, six require a reach and four a hurdle on the QWERTY keyboard.

These inconveniences are minimized by any of the numerous competing keyboard designs that concentrate the most common English letters onto the home row. For instance, the Dvorak keyboard devotes the home row to nine of the 12 most common English letters--including all five vowels and the three most common consonants (T, H, N)--while the six rarest letters (V, K, J, X, Q, and Z) are relegated to the bottom row. As a result, 70 percent of typing strokes remain on the home row, only 22 percent are on the upper row, and a mere 8 percent are on the hated bottom row; thousands of words can be typed with the home row alone; reaches are five times less frequent than in QWERTY typing, and hurdles hardly ever happen.

Another easily understood vice of the QWERTY keyboard has to do with alternation of hands. Whenever the left and right hands type alternate letters, one hand can be getting into position for the next letter while the other hand is typing the previous one. You can thereby fall into a steady rhythm and type quickly. In reality, though, even a good typist's speed is seldom steadily maintained. It repeatedly shifts between fast bursts and slow stutters within even a few seconds, and many of the stutters arise from strings of consecutive letters typed by the same hand. The longer the string, the slower the typing rate and the more frequent the errors.

Yet QWERTY typing tends to degenerate into long one-handed strings of letters, especially strings for the weak left hand. More than 3,000 English words utilize QWERTY's left hand alone, and about 300 the right hand alone. (Try typing exaggerated and greatest, then try million and monopoly). The underlying reason for this shortcoming is that most English syllables contain both vowels and consonants, but QWERTY assigns some vowels (A and E) as well as some common consonants (R, S, and D) to the left hand, and others (I, O, and U, plus H, L, and N) to the right hand. Hence, for about half of all digraphs (two consecutive letters) in a typical English text, QWERTY allocates both letters to the same hand.

The Dvorak keyboard instead forces you to alternate hands frequently. It does so by placing all vowels plus Y in the left hand, but the 13 most common consonants in the right. As a result, not a single word or even a single syllable can be typed with the right hand alone (no, grr isn't a word), and only a few words can be typed with the left hand alone.

QWERTY's many words and letter strings for the left hand are especially unfortunate when you consider that most people are right-handed. Yet QWERTY allocates to the weaker left hand the most common English letter (E), the second most common (T), and the fourth most common (A), thus making the left hand

perform more than half of all typing strokes (56 percent). We are condemned to struggle with a left-handed typewriter in a right-handed world. The Dvorak keyboard instead gives 56 percent of all strokes to the right hand.

QWERTY's overuse of our weaker hand extends to our weaker fingers. On each hand, the pinkie (fifth finger) is the weakest, and finger strength increases from the fifth to the second finger (index finger). Yet QWERTY makes almost as much use of our weakest finger (left fifth) as of our second strongest (right third). In contrast, the rank sequence of finger use on the Dvorak keyboard is identical to the rank sequence of finger strength, and the typing load on each finger is proportional to its strength.

The QWERTY keyboard also condemns us to awkward finger sequences. As we already know, strokes that alternate between hands are faster than successive strokes of the same hand. But if you must type two successive strokes with the same hand, it's fastest to do so with two remote fingers (such as at, left fifth to second finger), next fastest with two adjacent fingers (as, left fifth to fourth finger), slower with the same finger on the same row (ee, left third finger), and slowest of all with the same finger on different rows (ed, left third finger). Yet with the QWERTY keyboard, 20 percent of all English digraphs are typed by adjacent fingers, and more than 4 percent (such as the common ed) by the same finger; corresponding numbers for the Dvorak keyboard are only 2 percent and 1 percent, respectively.

The result of all these shortcomings is that typing on a QWERTY keyboard is unnecessarily tiring, slow, inaccurate, hard to learn, and hard to remember. In a normal workday a good typist's fingers cover up to 20 miles on a QWERTY keyboard, but only one mile on a Dvorak keyboard. QWERTY typists achieve barely half the speed of Dvorak typists, who hold most world records for typing speed. QWERTY typists make about twice the errors that Dvorak typists make. For a beginner to reach a speed of 40 words per minute, the person would need 56 hours of training on a QWERTY keyboard (an average of four hours per day during my two weeks of chicken pox) but only 18 hours on a Dvorak keyboard.

How, then, did the QWERTY keyboard arise? Why was it adopted, despite all its failings? And why in the world have we continued to stick with it?

The first recorded typewriter patent was filed in 1714 by the British engineer Henry Mill, for an artificial machine or method for the impressing or transcribing of letters singly or progressively one after another, as in writing . . . so neat and exact as not to be distinguished from print. But there's no evidence that Mill actually built his proposed machine. It was not until around 1808 that an Italian named Pellegrino Turri constructed a typewriter, which allowed a blind woman to write letters. Over the next six decades, several dozen inventors filed patents or built prototypes, but none of the machines entered mass production or attained commercial success. That had to wait until April 1874, when the American gun

manufacturer E. Remington & Sons, which had already branched out into sewing machines and farm tools, shipped its first Type Writer, based on a prototype by the American inventor Christopher Sholes.

From about 1880 to 1920, an incredible diversity of competing models poured forth from numerous inventors (including Thomas Edison) and manufacturers. Some of those early machines resembled pianos, some (including Remington's first product) looked like sewing machines, others were the recognizable ancestors of modern typewriters, and still others resembled no machine you have ever seen. Letters were variously mounted on separate type bars, on a single ball, or on a single wheel, strip, or plate. If separate type bars were used, they struck up, down, or sideways, behind or in front of the paper, which was mounted on a flat or curved carriage. What moved was the type ball carrier (as in the later ibm Selectric), the type bars (as in modern mechanical typewriters), or the machine itself. Ink was applied to a ribbon or directly to the typeface. The desired letter was chosen by striking a key or by turning a dial. Among machines that opted for striking a key, some struck one key at a time, others up to three at a time, like playing chords on a piano. The typist's left and right hands either typed on the same keyboard or on two separate keyboards.

We now have separate numeral keys, combine uppercase and lowercase letters on the same type bar, and choose between uppercase and lowercase forms of the same letter with a shift key. But other machines added numerals to that same bar and used two shift keys (one for uppercase, another for numerals), while still others had separate uppercase, lowercase, and numeral keys. Naturally, keyboards were equally diverse-- straight, curved, or circular, with one to nine rows of keys.

QWERTY was devised by Christopher Sholes, who began his typewriter-building experiments in 1867. Sholes's first keyboard used piano keys in a single row, with the letters in alphabetical order. But he was soon forced to change that arrangement, because his type bars responded sluggishly. When he struck one key soon after another, the second key's type bar jammed the first bar before the first could fall back, and the first letter was printed again. Key jamming was still an occasional problem some 80 years later, when I had chicken pox, but at least by then the type bars struck the paper from the front side, so you could immediately see what was happening and separate the keys with your fingers. Alas, with Sholes's machine and most other typewriters until the early part of the century, the type bars struck the invisible rear side of the paper, and you didn't know the bars had jammed until you pulled out the page and saw that you had typed 26 lines of uninterrupted E's instead of the Gettysburg Address.

To overcome the problem of invisible jamming, Sholes applied antiengineering principles with the goal of slowing down the typist and thus preventing the second bar from jamming the falling first bar. At that time, modern typing speeds were not yet a goal. The idea of eight-finger touch typing was still unknown.

Typists rummaged around with one or two fingers while looking at the keyboard, and Sholes was ecstatic if the resulting typing rate reached a measly 20 or 30 words per minute, the rate of writing by hand.

Sholes began to redesign his keyboard by commissioning a study to determine the most common letters or letter combinations in English texts, then he scattered those common letters as widely as possible over the keyboard. For example, the three most common letters (E, T, O) were placed in the top row, the next two most common (A, H) in the home row, and the next most common (N) on the bottom row, causing the common digraph on to require a hurdle from top row to bottom. Remington engineers slightly modified Sholes's almost-QWERTY design by transferring the common consonant R to the upper row, thereby enabling typewriter salesmen to show off their machine to prospective buyers by typing the word typewriter very quickly (all the letters were now in the same row). That final resulting keyboard still betrays its origin as an alphabetical arrangement of piano keys, by the nearly alphabetical sequence fghjkl in the home row, with de just to the left and I just to the right of that sequence.

The QWERTY keyboard of 1874 was eventually joined by many competing keyboards, whose manufacturers often boasted of faster or less tiring typing. For instance, the Hammond and Blickensderfer Ideal keyboard used only three rows and sensibly put the most common letters in the bottom row for easy access, in the sequence dhiatensor. Why did QWERTY nevertheless prevail, even after improvements in typewriter technology (reducing the jamming problem) and the demand for fast typing had removed the original motivation for it?

For one thing, QWERTY enjoyed a head start, as the keyboard layout of the first commercially successful typewriter. That success, however, was due not so much to the layout as to the many other advantageous components that Sholes added, such as type bars, an inked ribbon, and a cylindrical paper carriage. Those inventions helped Remington remain one of the leading typewriter manufacturers, and the company continued to use QWERTY even as its typewriters evolved in other respects.

QWERTY gained another undeserved advantage around 1893, when Underwood, Remington's chief rival, introduced a typewriter with two big virtues: visible typing on the front side of the paper, and a component called an accelerating sublever that permitted faster speed. Those features helped propel the Underwood Model No. 5 to the status of the most long- lived and widely sold office standard typewriter. Underwood happened to use the QWERTY keyboard.

QWERTY's early dominance meant that typewriter users became committed to the layout. From 1874 until 1881, the only typewriters commercially available were Remington machines with QWERTY keyboards, and typists learned to use them. Some of those typists set up typing schools, where they taught the QWERTY keyboard familiar to them. Their pupils took jobs at offices with the

keyboards they knew. Many businesses newly equipping themselves with typewriters ordered QWERTY machines, because it was easy to find typists trained to operate them.

Nevertheless, QWERTY's apotheosis came slowly. As of 1900, many typewriter engineers still disliked shift keys. But touch typing was prohibitively difficult with the alternative--a double keyboard with eight or nine rows of keys and separate keys dedicated to uppercase and lowercase letters. As touch typing gradually became the norm, sales of double- keyboard machines declined; the last model was discontinued in 1921.

The infinitely superior Dvorak keyboard is named for August Dvorak, a professor of education at the University of Washington in Seattle and a distant cousin of the famous Czech composer Antonin Dvo?rák. Around 1914, August's brother-in-law William Dealey attended some industrial efficiency seminars led by Frank and Lillian Gilbreth, watched their slow- motion films of typists, and reported what he saw to Dvorak. The brothers- in-law then devoted almost two decades to enormously detailed studies of typing, typists' errors, previously designed keyboards, hand physiology and function, and the relative frequencies of letters, pairs of letters, and words in English. Finally, in 1932, they took what they had learned and designed a new keyboard.

Dvorak typists began to sweep typing speed contests two years later, and they have held most typing records ever since. A large-scale comparative test of several thousand children, carried out in the Tacoma schools in the 1930s, showed that children learned Dvorak typing in one- third the time required to attain the same standard with QWERTY typing. When the U.S. Navy faced a shortage of trained typists in World War II, it experimented with retraining QWERTY typists to use Dvorak. The retraining quickly enabled the Navy's test typists to increase their typing accuracy by 68 percent and their speed by 74 percent. Faced with these convincing results, the Navy ordered thousands of Dvorak typewriters.

They never got them. The Treasury Department vetoed the Navy purchase order, probably for the same reason that has blocked acceptance of all improved, non-QWERTY keyboards for the last 80 years: the commitment to QWERTY of tens of millions of typists, teachers, salespeople, office managers, and manufacturers. Even when daisy wheels and computer printers replaced type bars, forever banishing the jamming problem that had originally motivated QWERTY, manufacturers of the efficient new technologies carried on the inefficient old keyboard. August Dvorak died in 1975, a bitter man: I'm tired of trying to do something worthwhile for the human race, he complained. They simply don't want to change!

QWERTY's saga illustrates a much broader phenomenon: how commitment shapes the history of technology and culture, often selecting which innovations

become entrenched and which are rejected. In the nineteenth-century United States, for example, those who profited from canals, barges, stagecoaches, and the pony express resisted the construction of railroads; in England, electric street lighting spread slowly, partly because of opposition from local governments with heavy investments in gas lighting. Even today, commitment influences railroad gauges and television technology, and whether we mark our rulers with centimeters or inches and drive on the right or the left.

Some of those choices, of course, make no real difference. But others do. The transistor was invented and patented in the United States in the 1940s. So why does Japan today dominate the world market for transistorized consumer electronics products? Because the company that became Sony bought transistor licensing rights from Western Electric at a time when the American consumer electronics industry was committed to churning out vacuum tube models and reluctant to compete with its own products.

The origins of many other commitments are now lost in remote history. How did China become committed to its beautiful but hard-to- memorize writing system? Chinese children can master pinyin (a Roman alphabet adapted to Chinese) in one-tenth the time required to learn the traditional writing system. Why do Americans cling to the awkward English measuring system of pounds, inches, and gallons? How did we become committed to decimal counting and a 24-hour clock? Would we have been better off with other choices?

Those questions are tantalizing but perhaps academic, because there is no prospect of our abolishing the 60-minute hour or reverting to base-60 counting, even if such changes did prove advantageous. But we do have the choice of discarding QWERTY in favor of the Dvorak keyboard. For QWERTY typists, learning the Dvorak keyboard is quick and painless, since they've already mastered the hard part of typing--coordinating finger movements. A common but specious objection is that it would be prohibitively expensive to convert existing QWERTY office machinery. In reality, mechanical typewriters are vanishing anyway, and the keyboard of any word processor or computer can be converted--or changed back--merely by pressing buttons.

The only real obstacle to our adoption of the Dvorak keyboard is that familiar fear of abandoning a long-held commitment. But if we were to overcome that fear, millions of our children would be able to learn to type with increased speed, greatly lowered finger fatigue, greater accuracy, and a reduced sense of frustration. That seems reason enough to end our commitment to QWERTY, a bad marriage that has long outlived its original justification.