MAN vs. MACHINE

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CAN'T PROGRAM YOUR VCR? SET YOUR DIGITAL WATCH? IT'S NOT YOUR FAULT. THE ENGINEERS JUST FORGOT THAT HUMANS WOULD BE USING THEM.

It is becoming increasingly clear that the comfort of a good fit between man and machine is largely absent from the technology of the information age.

Consider the humble wristwatch, which has been transformed into a kind of wrist-mounted personal computer, with a digital display and a calculator pad whose buttons are too small to be pressed by a human fingertip. In fact, the very usefulness of the digitization of time is open to question. People generally care less about knowing the time to the nanosecond than about seeing how long they've got until lunch. With digital watches, that requires a little figuring (the purpose of the calculator pad, perhaps), whereas with the old analog watches, the ones with hands, it's clear at a glance. Worse, by replacing the watch's conventional stem-winding mechanism with a mystifying arrangement of tiny buttons, the manufacturers created a watch that was very hard to reset.

One leading manufacturer was distressed to discover that a line of its particularly advanced digitals was being returned as defective by the thousands, even though the watches actually worked perfectly well. Further investigation revealed that they were coming back soon after purchase and thereafter in two large batches — in the spring and the fall, when the time changed.

Charles Mauro, a consultant in New York City, is a prominent member of a branch of engineering generally known as ergonomics, or human-factors — the only field specifically addressing the question of product usability. Mauro, who has won many awards for industrial design and human-factors research, was brought in to provide some help to the watch manufacturer, which was experiencing what Mauro calls "the complexity problem." With "complexity" defined as "a fundamental mismatch between the demands of a technology and the capabilities of its user," the term nicely captures the essence of our current technological predicament.

That mismatch might be measured by the increasing length of the instruction manuals required to work so many of the new gizmos. About the digital-watch manufacturer Mauro asks, "Can you believe that the company actually expected you to carry around a 30-page manual in your wallet?"

According to Mauro and other experts in the field, the solution to many such problems lies in a new approach to technological development called user-centered design. As the name suggests, this strategy takes the ultimate user into account from the very beginning of a product's development. Elementary as it sounds, this user-centered approach could drastically revamp American business.

DOMESTIC CONFUSION

The complexity problem is everywhere, but it is most apparent around the house. Americans' deficiencies in programming the VCR are so well known that they have become a staple of comedy. According to one consumer survey, a third of all VCR owners have given up trying to program their machines for time-delayed viewing. It is a measure of Americans' desperation that a multimillion dollar industry has sprung up to sell other technology, involving reference, numbers to provide assistance. And our troubles are not confined to the VCR. According to a survey by the marketing specialist Laurence Feldman, 50 percent of Americans can't work other programmable equipment either, and, thanks to the ubiquitous computer chip, that now includes almost everything: telephones, fax machines, thermostats, even coffee makers.

Soon we may add the house itself to the list, as plans proceed to link up these various unworkable components into a single unworkable whole, the "smart house," in which occupants will run everything — security system, coffee pot, kitchen stove — from a single remote-control unit at their fingertips.

When confronted by some mystifying piece of high-tech gadgetry, consumers naturally feel that there is something wrong with them if they can't figure it out. In truth it is usually not their fault. Mauro attributes the confusion to the fact that most products are "technology driven," their nature determined not by consumers and their needs and desires but by engineers who are too often entranced by the myriad capabilities of the microprocessors that lie at the devices' hearts. "They have this idea that if they can do something, they should," he says.

The main effect of the extra capabilities is in a great many cases to badly muddle the essential functions. Mauro was once hired by a sewing-machine manufacturer disturbed to learn that customers buying its latest high-tech sewing machines were abandoning them after a brief trial period and returning to their previous, supposedly outmoded models. Mauro quickly figured out why: "The new machines required as much mechanical training and information processing as it took to fly a light plane on instruments."

Donald Norman, a cognitive scientist now at Apple Computer, has written about such design screw-ups in "The Design of Everyday Things." Besides the malady he terms "feature-itis" he describes a number of common design bloopers that boost technological complexity. There is "bad mapping," in which, for example, the burners of a stove are arranged in a square but the controls are in a row, necessitating labels such as “RF” and “LR” to designate which knob governs which burner; a lack of “forced constraints” to ensure that a user will perform each programming step correctly before going on to the next one; and the absence of feedback, such as the beep emitted by a pressed telephone key, to reassure the user that a system is working.

But beneath it all, Norman believes, the fundamental confusion is due to the essentially inscrutable nature of the technology itself. “In the mechanical systems of the old days you could wiggle a knob or a lever and see something happen,” he says. “Today’s technology concerns information that is invisible and abstract, so the designers have to give a sense of control by different means.”

All too often those means are dense instruction manuals, which Mauro regards as the clearest sign of design failure. The best-designed products require no instructions at all: their appearance tells you what to do as surely as a coffee mug’s handle says “Hold here.” This notion is reinforced by product-liability laws, which first consider the product’s physical design, then its labeling, and finally its instructions. In the minds of most engineers that list is inverted.

According to Alan Frank, a consumer-products specialist at the telecommunications firm BNR Ltd., the “manufacturer’s showroom mentality” also adds complexity. The extra features are merely an eye-catching consumer come-on, not unlike the chrome on a 1952 DeSoto; they are never intended to serve any real purpose. In their eagerness to outdo their rivals, many manufacturers engage in a kind of features warfare. If one company offers 12 buttons, another must offer 15.

Manufacturers themselves are under few illusions that the added features do anyone any good. Amar Bose, the founder and chairman of Bose Corporation, has worked for years to simplify the controls on his company’s stereo equipment. He is always shocked by the graphic equalizers he encounters in rental cars. “It makes the music sound absolutely terrible,” he says, putting his hands to his ears.

The need for product differentiation produces another misery for consumers, which is that no two products in any category ever work the same way. In the human-factors world this is known as the negative-transfer problem, and it has added a good deal to consumers’ cognitive overload.

To take one small but revealing example, the telephone industry is engaged in a heated dispute over the question of where to add the letters Q and. Z, now missing from conventional keypads, to complete the alphabet for the newly automated caller-interactive switch boards. Some companies put the Q and Z on the 1 key, which otherwise has no letters. Others, led by AT&T, have put them in alphabetical order on the 7 and 9 keys, even though that has meant adding a fourth letter to each. “You wouldn’t believe how many studies have been done on this,” says Miriam Kotsonis, a technical manager at AT&T’s Bell Laboratories. “We concluded, You don’t mess with the alphabet.”

MATCHING MACHINE.S TO PEOPLE

From robots to lasers, industrial technology is infinitely more high-powered and challenging than the household variety. Companies can pay their employees to devote their working lives to learning how to operate a single piece of equipment, and they take full advantage of this fact, ratcheting up the cognitive demands to the point where they pose a real strain and in some cases a positive hazard. These machines are VCRs from hell.

Stuart Card, a cognitive psychologist and computer scientist at Xerox Palo Alto Research Center (PARC), holds up a paperback-sized Hewlett-Packard calculator. It performs 2,100 functions, all of them explained in a 700-page manual. Card marvels, "You can even set it to perform certain functions at certain times — say, to do a symbolic evaluation of an integral at 12:04 p.m. on January 12 in the year 2014." Not that he knows why anyone would want to. "They brook no compromise at Hewlett-Packard. Their idea is that if you can't work this thing, you're not good enough."

Some users, not surprisingly, have come to resent the computers that have transformed their work lives so drastically. Mauro was once called in to a newly automated paper mill where workmen were sabotaging the system by deliberately entering incorrect information into the computers and, if all else failed, hosing the computers down until they shorted out. "The workmen were frustrated that the company demanded greater productivity from them while depriving them of the control over the machinery to deliver it," Mauro says. "They were caught in a terrible bind."

In the early stages of the computer revolution it was tempting to view the emerging man-machine mismatch as an issue best addressed by ergonomics. The field has roots in Frederick Winslow Taylor's time-and-motion studies at the turn of the century, but it first flowered during the Second World War, when the fate of the Allies hinged on soldiers' ability to work complicated machinery. For example, Alphonse Chapanis, one of the fathers of the modern human-factors movement, examined the mysterious runway crashes of B-17s which composed one of the largest categories of noncombat accidents in the war. Chapanis discovered that the plane's cockpit had two identical toggle switches side by side, one to raise the flaps, the other to raise the landing gear. Exhausted at the end of a long flight, the pilots inadvertently pulled up the landing gear rather than the flaps. Their planes plunged down onto the tarmac and sometimes burst into flames. The Allies' human-factors work may have proved decisive in the air war, because it allowed pilots to fly fighter planes with less training than they might otherwise have needed.

After the war human-factors specialists worked to fit machines to men. They tended to focus on physical interaction, making endless anthropometric measurements to determine the range of human foot size, fingertip width, peripheral vision, hearing perception, color sensitivity, and the like. Such issues should certainly not be overlooked: the first wave of Japanese cars into the United States, for example, failed to catch on largely because their makers had underestimated the length of the average American's legs, and produced cars that felt cramped to U.S. buyers.

But there are other issues to be addressed. It is perhaps an index of the very complexity of the complexity problem that no one field can fully address it, and human factors is no exception. One reason that complexity has gotten so far out of hand is that it has come to reflect the divergent interests of the forces that shape the technology in the first place.

"There are basically two camps," Charles Mauro says. "You've got the engineers and designers on the one side, and you've got the psychologists and the applied psychologists on the other. The two groups are constitutionally unable to talk to each other : Basically, the psychologists define problems and the engineers propose solutions. The human-factors people get on a track where they think they're both designers and engineers, when in fact they're neither. But you get in real trouble when designers start thinking they're psychologists."

Most human-factors specialists are too physically oriented to address successfully the heavily cognitive issues imposed by today's technology. But then, few engineers are likely to give them a chance to, since engineers believe they can speak for the user perfectly well themselves. "Engineers have this idea that since I'm human and I'm an engineer, I'm a human engineer," Mauro says, referring to another term for a human-factors specialist. Such attitudes may explain why some human-factors professionals often do more work presenting expert testimony in product-liability cases than they do helping to design workable products in the first place.

Mauro has devised something he calls the User Merit Index, largely in order to present the usability issue in numerical terms that engineers can appreciate, His index plots the difficulty of various aspects of operating a technological device, from turning it on to programming it. He has been amazed by how avidly engineers will attack a problem once it has a number.

WHAT COMES NATURALLY

The engineers' blindness to consumers' needs may be at the root of a deeper problem — how so much baffling technology enters the market. Donald Norman blames it on the "waterfall method": new technological equipment tumbles out of a corporation, never encountering a typical user until it is bought.

A growing number of technologists think that the development process should be reversed, and they speak of user-centered design as a means of scrupulously maintaining the user's perspective from start to finish, adding technology only where necessary to accomplish a particular task.

Far from being a simple idea, user-centered design has a host of implications for technology around the house, at work, and in the military. The key principle is not to assume that more technology is always better.

The design of AT&T's new videophone, for example, shows the advantages of the user-centered approach — and illustrates the battle a company often faces in trying to keep things simple. "To tell you the truth," says AT&T's Miriam Kotsonis, "when the company first thought about the product, the techies started to go wild, dreaming about a camcorder that lets you make phone calls, with a zoom lens and pans and tilts, and all that. But we said, 'Let's not make this so hard for our customers. Let's make this as natural as holding a telephone.'"

In the debate between those who cared primarily about technology and those who cared primarily about users, the defining moment during the planning came over the question of how to handle "self-view" mode, which allows users to check their appearance before each transmission. The technologists were inclined to present the image as the camera sees it, with the left side of one's face on the right side of the screen. But the user-centered designers knew that people expected a mirror image, with the left side of the face on the left side of the screen, and in the end that is what they got. The technology was strained so that the user would not be. At its best, user centered design can seem almost poetic in its grasp of human nature.

Much of the work is a matter of finding the "mental models" — like the mirror mode — by which users instinctively interpret a technology. Especially when the workings of a device are invisible, these models may very well be erroneous.

For instance, many people set an electric burner on high thinking that it will heat up faster that way: They have the mental model of a gas stove, whose knobs actually do increase the heat's intensity. On an electric stove, however, the knob is merely a switch that turns on the burner and then turns it off when a certain temperature is reached.

Some designers are trying to restore the logic to otherwise arbitrary controls through what they term "product semantics," which evokes a natural-seeming vocabulary for things like control knobs. A good example is the "up" and "down" designations for the power-window control introduced on the Ford Taurus. The "up" side is marked by a convex surface, the "down" side by a concave one.

No single approach will eliminate all the complexity problems posed by current technology. But user-centered design can certainly help solve these problems, if only by encouraging manufacturers to consider the needs and abilities of the average user early on in the product-development process.

With VCRs, a truly user-centered manufacturer would have recognized that programming them might prove extremely difficult for the average person and would have taken steps to simplify the process. It would have helped, for instance, to have the VCR's controls all visible, the way a typewriter's are, rather than having them be accessed by a series of complicated commands, like a personal computer's.

By the same token, a user-centered digital-watch maker would not have tried to introduce a whole new, mind-bending system of resetting the time by pressing tiny buttons but would instead have relied on the well-established model of the stem-winding mechanism.

User-centered design would probably also encourage businesses simply to forgot about certain ill-conceived products like the "smart house." "That's an engineer's idea of user-centered design," Mauro says. "Nobody went out and asked anyone if it would make his life at home better. Some engineer thought, 'Gee, we have all this great technology to control electrical systems and information systems. Let's try to do something with it.'"

Mauro would even jettison the so-called user-agent, a piece of computer programming that is being advocated in some circles as a way of assisting us in certain routine aspects of our lives. In one configuration a user-agent could produce a customized newspaper from a computer network by pulling out articles on topics — the Texas Rangers, the stock price of Pfizer — that are known to be of interest to the individual reader. Mauro believes that such a strategy fails the essential test for user-centeredness because it overlooks one reason that most people read newspapers — for those odd bits of information that are interesting precisely because they are outside one's experience.

User-centered design might even be able to forestall accidents, by dictating that mock-ups of a product be tested with users before it goes into full production. Too often manufacturers don't realize the hazards their products present until the liability lawsuits start coming in, which may explain why product-liability law is such a lucrative segment of the legal profession.

The consulting firm of Bolt Beranek and Newman has developed a piece of software dubbed the "mythical man" to test the cognitive workloads required by certain military flight-control equipment — while it is still in development. The company has also come up with something called simulator networking, or SIMNET, an extraordinarily realistic audio-video simulation of operating an M-1 tank, among other vehicles. SIMNET was designed to allow soldiers to train on a battalion of M-1s under battle conditions without actually being shot at. Because it is an easily alterable software package, SIMNET has proved helpful in testing the usability of new tank designs as well.

User-centered design applies no less to a large technology such as nuclear power. Mauro served on a nuclear-power task force in the aftermath of the near-meltdown at Three Mile Island. In his opinion, safety issues have been badly neglected by most nuclear designers. "Most nuclear power stations were designed primarily to accommodate the latest engineering theories and other political and technological issues," he says. "Only after they were built did anyone ask if human decision-making was properly factored into the system to make it safe."

One way to build safety in from the start would be to require that all control rooms be highly standardized, as they are in France, to allow standardized training and also to facilitate outside intervention in an emergency. As it is, most individual nuclear plants in the United States have gone to considerable expense to produce exact reproductions of their control rooms for training purposes — yet most important skills are not directly transferable to any other plant.

Similarly, user-centered design in the military could reduce the hazards of friendly fire for ground vehicles by having them emit the electronic signals indicating "ally" that have long been standard on military airplanes. Only after the calamities of the Persian Gulf War did military designers recognize this problem.

NEW GENRES

User-centered design is not easy to implement, first because it means revamping the way that technology reaches the marketplace, and second because it calls on a broad range of expertise — in marketing, human factors, psychology, sociology — that is rarely found in one place. "You can't just hire a user-centered-design person," Mauro says.

For these reasons very few companies in the country are doing much user-centered design. One of the few is Xerox, whose Palo Alto Research Center is using these principles to redesign the personal computer. "We want to use the incredible technological power inside the box to create simplicity outside," says John Seely Brown, a chief scientist at Xerox and the director of PARC. Rather than blindly creating more features, PARC is harnessing the power of the computer to make it easier to use.

Apple's Macintosh computer, using innovations developed at PARC, has set the standard for user-friendliness with its representational icons, such as a trash can (to get rid of a document) and a manila folder (to collect a group of files). But such symbols have served mainly to lessen resistance to computers; they do little to enhance the operator's power over the machine once he or she has gotten going. Some even argue that user-friendliness actually reduces control for the experienced user, just as automatic transmission takes something away from drivers accustomed to standard transmission.

Xerox PARC has responded to this argument by trying to break the computer out of its box entirely, scrapping the conventional configuration of keyboard, central processing unit and screen. In order to bring more power to a business meeting, one group has computerized a white board, adding such basic computer functions as saving and editing to a large computer screen on which users draw by hand.

Another PARC group, led by Stuart Card, has added depth to the flat world of conventional personal-computer screens through the use of 3D, virtual reality and Disneyesque animation. This is perhaps the ultimate in user-centeredness: It allows the operator to all but enter into the data. The three-dimensionality means that there is a place to stash a lot of background data while the user focuses on the foreground. The resulting information is wonderfully concentrated. The system can present the top 600 senior managers of Xerox on a single screen by arranging the hierarchy in the shape of a 12-inch-high 3D Christmas tree (this has the added benefit of showing the relationships among the various jobholders). Without depth such a list would shoot up to 12 feet high.

Depth also makes possible a more natural arrangement for clusters of information.

Instead of the "windows" on the current generation of personal computers, Card's team developed the concept of 3D "rooms," one for each project, connected by "doors." With 3D the system can rely on the user's natural intuitions, developed in the real world, and arrange the various entries like sections of a private library. It also allows the user to visualize a long list of files by viewing them as if on three sides of a folding screen, which angles out from and back into deep space as the files scroll by.

More startling still, the system allows the mapping of information into lifelike 3D space through computer graphics. In one configuration, Card took me on a tour of the lab itself, occasionally veering off to land on a ceiling or settle on a wall. The world of the computer had become the world of the world.

User-centered design can go only so far to make a new technological system seem natural, though. Some operations simply have to be learned. For instance, does a computer's up arrow mean that the text goes up (and the screen down) or the screen goes up (and the text down)? Neither mental model is more intuitive than the other; the correct answer has to be memorized.

Over time such things become natural, just as driving a car does — both for individuals and for society. But it does take time. John Seely Brown explains the process for society as a whole as a matter of developing the appropriate technological "genres." Just as popular culture has genres (the romance novel, the slasher flick) to help people interpret a new experience, so technology has genres (the motorcycle, the calculator) to help people come to terms with a new product. In Brown's view, the problem is that technology is coming out faster than the "social mind" can establish genres for it.

"In the old days there was real stability," Brown says. "A piece of technology stayed on so long that we had a wonderful, socially constructed genre that helped us read the technology and inform our views. Now the technology is changing so fast that the genre doesn't have time to get enacted or constructed."

Brown took me down a hall to look at a high-powered Xerox 5100 copier, which, he told me, embodies many of the principles he had just been discussing. The machine itself does the bulk of the work, of course, but it allows the operator to direct and oversee the process via an icon-laden touch-sensitive computer on top of the machine, which presents a visual display of the internal operation. The whole business seems somehow comfortable, human. The housing is clean and spare, the image of order. Should you need to investigate the cabinet underneath, the color scheme tells you most of what you need to know: Red says don't touch, green says grasp here. Brown shut the cabinet door and ran a hand lovingly along the smooth exterior. "This is very nicely designed," he said with a smile. "The scary part is all inside."