Trends

Cybersickness: The Side Effects of Virtual Reality

Certain events never occur on the "holodeck," a virtual environment on *Star Trek*'s twenty-fourth-century starship *Enterprise*, where holograms are so realistic they are indistinguishable from reality. Captain Jean-Luc Picard does not conclude his fantasy life as a hard-boiled, pulp-fiction detective by puking all over the ship's clean floors. When second-in-command William Riker leaves off a romance with a computer-simulated dance-hall girl, he does not traipse back to the helm to fire a photon torpedo when he merely means to hail an alien ship. And Geordi La Forge, the ship's engineer, does not experience flashbacks the day after he confers with a holographic projection of the designers who created the ship's engine.

Unfortunately, such side effects and more bedevil users of today's virtual reality simulations. Such symptoms have been noted since the late 1950s, but in the last 20 years, studies by both the military and the National Aeronautics and Space Administration (NASA) have shown just how extensive simulator sickness and cyber side effects really are. In 1987 John Caseli, director of the auditory systems laboratory at Virginia Polytechnic Institute, surveyed available data and found that the rates of all types of simulator sickness ranged up to 90 percent, depending on the simulator. Another survey by Robert Kennedy, a psychologist with the Orlando branch of Essex Corp., which specializes in human-machine interactions, suggests that an average of 30 percent of people who use some kind of simulator exhibit classic symptoms of motion sickness, such as cold sweats, nausea, and vomiting.

In a generic sense, virtual reality is any technology in which a person interacts with a computer-generated world that appears more or less real. Of late the term has come to describe a truly immersive environment where users wear head-mounted displays with earphones and a screen in front of each eye showing projections of computer-generated images that encompass a person's entire field of vision. As the user's head turns, the scene shifts accordingly, and special gloves transmit motion signals to the computer, which then responds by moving simulated objects on screen.

Most people who suffer cybersickness from using this technology may sweat, salivate, turn pale, as well as experience headaches, fatigue, and nausea. (*See "Knowing Where Your Head Is At," TR February/March 1995, page 10.*) But what most worries psychologists who study the phenomena is the dramatic disorientation that can occur. For example, Frank Biocca at the University of North Carolina at Chapel Hill once had a colleague test a virtual reality headset designed to show doctors how organs and muscles were likely to appear inside the bodies they were cutting open. "When she took off the headset and went to drink from a can of soda, she found she was pouring the soda into her eyes," he says. "You can see that this has distressing implications in a system intended to be used in the operating room."

And then there are the flashbacks. Kennedy recounts a pilot's vivid flashback while driving his car the day after he operated a simulator. "He had to pull over to the side of the road and walk around and touch things to see if they were real," he says.

No one is quite sure how long these various side effects last. But one study by Kennedy and his colleagues found that 14 percent of helicopter pilots who trained in a simulator reported motion sickness symptoms lasting more than 6 hours, while other studies found flashbacks, balance disturbances, and disorientation lasting up to 12 hours. The

ILLUSTRATION: ROB SCHUSTER

where to apply voltages to forge desired connections. This circuitry occupies prime semiconductor real estate that is then unavailable for the chip to do its intended job.

In the past few years, a different method of finishing gate arrays has arrived on the scene. This technique starts with a gate array that has been totally interconnected: the output of every gate is connected to the input of every other gate. To customize the chip, a product manufacturer—a computer company, for example—uses a laser to sever all the connections *except* for the ones needed in the specified design. This "break link" process is like buying a 500-room house and then creating the desired floor plan by knocking down 450 of the dividing walls.

Gentler Connections

But severing a connection requires an intense laser pulse; as chip designers cram more and more circuitry onto each piece of silicon, such an energetic burst could ruin the delicate transistors close to the beam, says electrical engineer Joseph Bernstein, who left MIT's Lincoln Lab in June to become a professor of materials and nuclear engineering at the University of Maryland.

Bernstein has devised a prototype-finishing technique that uses lower laser energies and thus, he reasons, should work well for densely packed chips. His chief innovation is to use the laser beam not to break connections but to make them. He shines a beam onto two adjacent lines of metal with just enough energy to melt each one. The molten puddles coalesce and cool to leave a new electrical pathway. Making links in this fashion requires only about one-fifth as much laser energy as breaking links, Bernstein says. The ability to use a gentler laser beam, he asserts, also lowers the risk of damaging nearby transistors.

The laser make-link process should actually become more effective as transistor density rises, Bernstein claims. In fact, he says, the process has become feasible only as the distance between lines of metal has dropped below one micron. And as semiconductor devices continue their inevitable shrinkage, the process would require only a tighter focusing of the laser beam to retain its usefulness. That shouldn't be a problem: the infrared laser Bernstein uses can be focused to a spot as small as 0.35 micron, which should take care of devices envisioned for the remainder of the decade.

—*Herb Brody and Laura van Dam*

effects are so pronounced that the Army, Navy, Marines, and NASA won't let people who experience cybersickness fly or drive until 24 hours after the symptoms subside.

Younger individuals appear even more prone to the effects. An analysis by Kennedy suggests that the likelihood of exhibiting symptoms is greatest between the ages of 2 and 21 and dramatically diminished after the age of 50. "This is bad news for companies that make virtual reality systems," says Biocca, "because this is precisely the group that is most likely to buy them."

A Lawsuit in the Making?

Industry analysts say cybersickness may create roadblocks to greater use of a technology that is expected to constitute a third of the market for home video games by the end of the century. In fact, experts predict it's only a matter of time before virtual reality system manufacturers will be hauled into the courtroom because of accidents stemming from the psychological side effects. "The big concern is little Johnny who spends four hours a day inside his virtual headset," says Arthur Zwern, president of the General Reality Co. in San Jose, Calif., which makes headsets used in virtual systems. "All it will take is one kid getting hurt and there will be a big brouhaha. It will be like the Pinto's exploding gas tank."

Why do people suffer cyber side effects? The most widely accepted explanation is that they result from a sensory conflict between what you see and what you think you should be seeing. If you think something is over to the left, your eyes turn and look left. But even in the best simulators there is a certain lag time for the computer images to react to the user's head and body movement. Even delays as short as a third of a second can confuse the brain and the inner ear's balance system.

Why exactly this should produce nausea, coordination problems, and flashbacks is not entirely clear. Kenneth Money, a former Canadian astronaut and now a motion researcher at the Defense and Civil Institute of Environmental Medicine in Downsview, Ontario, has done studies with dogs suggesting an unexplained connection between the body's sense of balance and its response to ingesting something disagreeable like a poison. When the brain gets the message—whether from actual motion or a computer simulation—that the body is being thrown off balance, it may accidentally trigger the anti-poison response of nausea and vomiting.

Money says that coordination problems may simply be a result of the body adjusting to the real world in the same way that we need time to adjust to walking on solid ground after being on a ship for any length of time. And he thinks the flashbacks may be an extreme déjà vu experience, whereby some cue in the real world vividly reminds the user of a recent experience in virtual reality.

Although the evidence of cybersickness is well-documented, it is virtually never mentioned during discussions of the technology. One reason may be that developers are too absorbed in getting their application to work. In fact, it is usually not until after the design is frozen, says Kennedy, that the effect of a game on humans is considered. For example, after a year of promoting a $200 home virtual reality game for its Genesis 16 system, Sega Corp. announced in January that it would not be selling the system after all. Thomas Piantanida, a researcher with SRI International, an independent research company in Palo Alto that evaluated the prototypes, told colleagues at a scientific meeting that some 40 percent of Sega's users were experiencing cybersickness.

Some companies have begun addressing the problem by reducing the immersive nature of their games to cue the brain that the time lags it picks up should not be taken for real. By cutting down the field of view, for example, and allowing users to see their feet, they can create an effect more like that of a television set floating before their eyes. That way, users can see other parts of the real world around the projections.

Limiting the time users spend on a machine is also a clear safety feature, since numerous studies have shown that the likelihood of cybersickness rises with the length of such time. For example, researchers at Emory University and the Georgia Institute of Technology, who recently reported that they were able to help people overcome their fear of heights using a virtual reality application (*see "Facing Real Fears in Virtual Worlds," TR May/June 1995, page 16*), found the treatment worked only after each session was cut from about an hour to 35 minutes. Longer immersion periods were making people more cybersick than height sick.

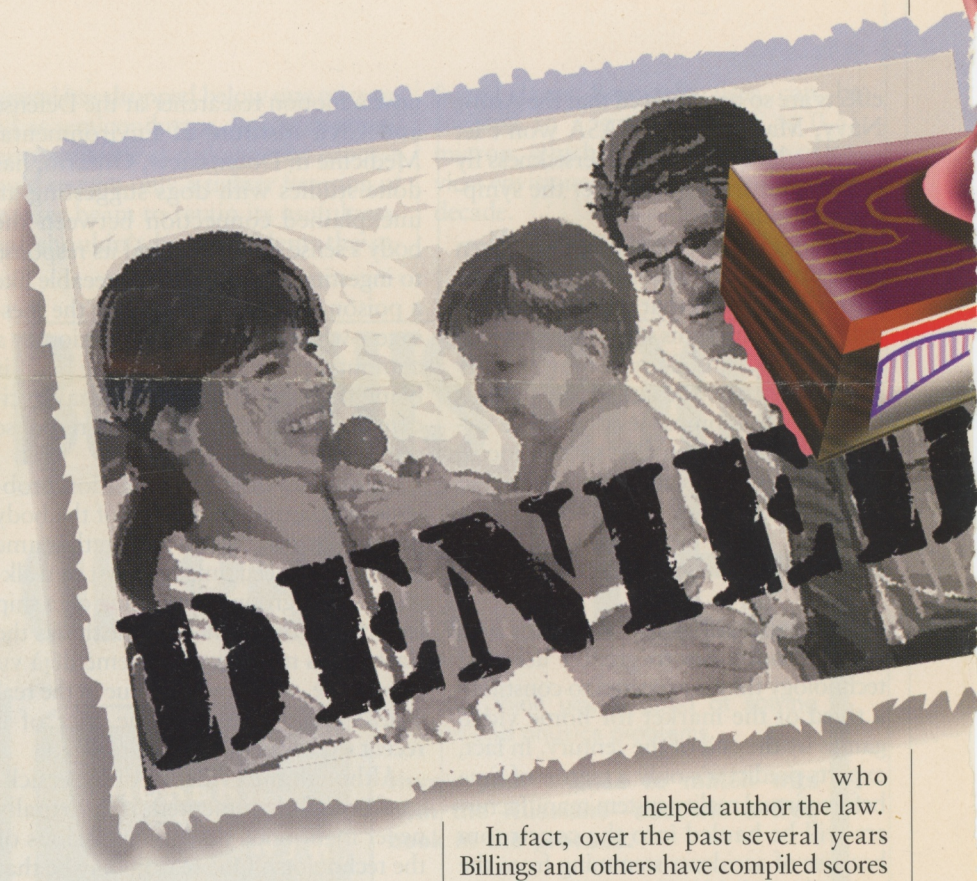
Reducing Lag Time

And some applications are more likely to create sicknesses than others—for example, anything with lots of unexpected changes in motion and body placement. Unfortunately, it is just these sorts of movements that give games their kick. "If you adjust too many parameters and too many people get sick it is a bad ride, but if you make the realism factor too low and people don't get sick, then it's also a bad ride," said Biocca.

Finally, some people think that ever-increasing computer power will prove the salvation of virtual reality. If the lag time can essentially be reduced to zero, so should the sickness. "We don't get sick in the real world, so if we had complete fidelity, we wouldn't get sick in the virtual world," says Malcolm Cohen, a senior scientist with the NASA Ames Research Laboratory, which builds and tests simulators.

But less sanguine researchers point out that time lag may not be entirely responsible. For example, a number of unlucky fliers get airsick on even the smoothest flights, perhaps because of the discordance between sitting still and, say, watching the rapid motion of clouds out the window, which suggests that a significant subset of virtual reality users will always get sick, too.

—*STEPHEN STRAUSS*



Preventing Genetic Discrimination

In California, it is now a matter of state law: you cannot be considered sick until you exhibit symptoms. The pathbreaking legislation to legally designate the onset of illness is not as silly as it may sound. Rather, proponents say, it is necessary to prevent insurance companies and employers from unfairly discriminating against people on the basis of information about their genetic makeup or that of their families, even though they are completely healthy.

Because hundreds of tests are now available to identify an individual's genetic predisposition to rare inherited disorders, and dozens of others are in the pipeline to predict more common illnesses, protecting this new class of potential victims, "the asymptomatic ill," is becoming more urgent, says Paul Billings, a San Francisco-based physician who helped author the law.

In fact, over the past several years Billings and others have compiled scores of cases of healthy individuals at risk of developing inherited conditions who have been denied health insurance. Women giving birth to babies diagnosed before delivery with genetic disabilities have had to fight for coverage. Even people with hereditary disorders already successfully treated have been refused policies. In all such cases, the lack of insurance threatens to curtail access to health care and leave the individuals financially vulnerable to huge medical bills, whether for the inherited disorder or any other.

Daniel Keife, a controller at the James Jones Co. outside Los Angeles, was rejected from his firm's health-insurance policy because he and his son carry a gene for the disfiguring and potentially lethal condition known as neurofibromatosis. Keife's son exhibits the disease's symptoms of multiple tumors and paralysis, but Keife himself has been spared such complications. "I could understand excluding my son," Keife says, "but if I were going to be severely affected, it would have happened by now."

ILLUSTRATION: ANDREA SUTTON