



Playing by Ear

Audio-based computer games are helping blind volunteers learn navigation skills and may unlock mysteries of the sightless mind

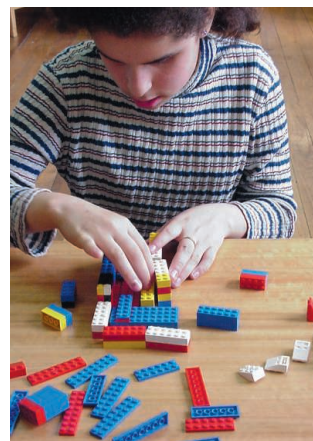
BOSTON—Like the dull, bare walls of the classroom here at the Carroll Center for the Blind, the video game that 28-year-old Rachel Buchanan is playing on a laptop isn't much to look at. Onscreen, there's just a simple rendition of the floor plan of one of the center's administrative buildings, laid out on a grid with each cell corresponding to one step. Though blind since childhood as the result of optic nerve damage, Buchanan navigates her game avatar through the maze quickly, keeping it close to the walls like someone guiding themselves by touch. The secret to her speed is inside the headphones Buchanan wears, which immerse her in a three-dimensional labyrinth of sound.

A knock in one earphone or the other indicates a door on that side. The sound of footsteps ascends in tone as Buchanan walks her avatar up stairs. Furniture pings when bumped, and the jewels she is seeking twinkle more loudly as she approaches them. All in all, Buchanan says she feels physically present in the maze's corridors. "Ah! Go away!" she yelps suddenly at one point when she hears the warning of a passing "monster"—her fingers fly over the keys to skitter her avatar toward safety, into a section that announces itself as "Women's Bathroom."

Once they drag Buchanan away from the game and into the real building next door—

thankfully free of monsters—neuroscientist Lotfi Merabet and study coordinator Erin Connors, both of the Massachusetts Eye and Ear Infirmary, instruct her to go to various rooms and exits, noting the routes she takes. Like the other blind volunteers in Merabet's study, she had never been in the building before playing the Audio-Based Environment Simulator (AbES, pronounced "abbess") game. But after just half an hour of monster-dodging and jewel-hunting in the virtual building, these gamers learn its layout so well that they can quickly navigate themselves to any room in the real building.

A rehabilitation therapist and self-proclaimed computer-game enthusiast, Buchanan, Merabet says, is one of the "rock stars" among those who have participated in his studies of computer games as indoor navigational tools for the blind. So far, 10 volunteers between the ages of 18 and 45, all of them blind since birth, have played the AbES game and then successfully navigated the actual



Virtual cartography. Blind children who played an audio version of the computer game DOOM could use blocks to reconstruct its map from memory.

Mind games. Wearing headphones that let them use audio cues to navigate maze-based computer games, volunteers play while their brain activity is scanned in an fMRI machine.

administrative building. Those are encouraging results as indoor navigation, where GPS systems don't work and guide dogs aren't always welcome, is a special challenge for many blind people.

AbES "frees the blind from relying on special devices to navigate when all they need is already embedded in their brain," says cognitive neuroscientist Ladan Shams of the University of California, Los Angeles. "That must be very liberating." The goal, adds neuroscientist Franco Lepore of the University of Montreal in Canada, would be for the blind gamers to learn to develop maps that the sighted build subconsciously, so that when deciding to go to a place, the directions will just "click in your mind."

Still, Merabet is hoping to do more than use AbES to help the blind. With funding from the National Eye Institute, he and colleagues have begun imaging the brain activity of both blind and sighted people as they play the game. The comparison is meant to reveal how the navigation techniques used by blind and the sighted brains differ. "Myths abound," he says, about how the blind learn, as well as about what they can and cannot do, such as grasp abstract visual concepts. As neuroscientists working at the edge of the educational community, "we can come with the data to prove that they are myths." Game navigation, he adds, "is an interesting neuroscience question that happens to have an end product."

The streets of Santiago

AbES has its roots in the streets of Santiago, Chile, a place where blind children are among the poorest children in the city; they wouldn't normally have access to cutting-edge technology as do Buchanan and the students at the well-endowed Carroll Center. Yet thanks to computer scientist Jaime Sánchez, it was the kids of Santiago who nearly 20 years ago got to play-test the first

audio-based computer game for the blind.

Sánchez, a researcher at the University of Chile in the city, had been working on educational computer games in the early days of the industry in the 1980s. In 1993, he and the whole gaming industry experienced the DOOM revolution. DOOM was the first popular game to present a three-dimensional field of action at eye level rather than from a bird's-eye view above. A DOOM player had to navigate an avatar through its infamously complex map of corridors while simultaneously spotting and mowing down demons with a machine gun. Similar games, known as first-person shooters, now dominate much of the video-game industry.

Sánchez, who was working on developing audio-based games as learning tools for disabled children, wondered whether they could navigate DOOM's unique system. He used the map as the basis for his own game, AudioDOOM, which he released in 1998. The "mother of AbES," AudioDOOM incorporated a similar system of sound-emitting walls, as well as monsters that run toward the player with increasingly loud footsteps. Sánchez recruited half a dozen children between the ages of 8 and 11, all blind since birth and mostly from poor neighborhoods, and watched the children play the game in their homes or schools.

As a proof of the idea that the blind could navigate a computerized map using only sound, AudioDOOM was an "astonishing" success, Sánchez says. Curious as to how well they had learned the game's map, the researchers also gave the children building blocks and asked them to reconstruct it from memory. Although they hadn't been instructed to keep track of their movements while playing, the children were all able to recreate the map to scale.

Sánchez wondered whether this ability was unique to blind children, so the researchers recruited sighted children of the same age and from the same area of Santiago and had them play AudioDOOM while blindfolded. They did poorly. Despite the auditory cues, the sighted children hadn't even realized they were in corridors, and their reconstructions were a mess.

Sánchez and Merabet met at a conference in 2008, and the two agreed to collaborate on studying the differences between blind and sighted gamers. Suspecting that similar audio-based games would have potential as a rehabilitation tool, the pair sought to make a game located in a place, complete with open spaces and multiple floors, that actu-

ally exists. They found a home for the AbES project at the Carroll Center, where Merabet could both recruit subjects and run tests.

The arguments for using such games to teach navigation are numerous, he and Sánchez contend. The games are simple for the blind students to play: "We don't have to teach them anything," Merabet says. And while plenty of research has demonstrated the effectiveness of virtual reality systems as training and navigation aids, the researchers speculated that putting these tools in the context of a game would make people play longer while still learning subconsciously. And even if AbES didn't turn out to be good at teaching navigation, at worst the blind students at the Carroll Center would have a new game.



Off the grid. Playing a virtual auditory game teaches blind research participants such as Rachel Buchanan (with cane) the layout of a real building.

Yet AbES proved effective right away, Merabet reported at the Envision Conference in St. Louis, Missouri, last week. The researchers directed half of the blind students through AbES's virtual building as though taking them on a tour. The others were left to explore on their own in a "game mode," complete with jewels and monsters. When the researchers then assessed the blind students' ability to navigate the real building, all of them could easily find any room or exit. But there was a subtle difference between the two groups: Students who had played in game mode for half an hour were significantly more creative at finding the quickest route to an exit. Those who had been led were far less efficient.

That's because play is a more natural way to navigate, Merabet speculates. With a challenge, a reward system, and a way to hold a player's attention, video games mirror "the way the brain likes to work," he says.

AbES could also teach the blind how to infer directions, says experimental psychologist Nicholas Giudice of the University

of Maine, Orono. With most rehabilitation and navigation training, says Giudice, who is blind himself, "there's an emphasis on route learning and not enough on how to build a cognitive map" that would allow creative problem-solving. After all, if a route is blocked, it's useless. "If something like Lotfi's game can get people to think in these global contexts, that's going to affect almost everything they do" with spatial tasks, he says.

Just a few more minutes

Merabet and Sánchez are currently working on an "AudioZelda" version of AbES that maps the entire campus. Similar to the famous video game Legend of Zelda, play-



ers will have to run from building to building collecting jewels as well as keys to the different buildings. Sánchez has also developed a game for the blind based on the Metro de Santiago—the second largest underground metro system in Latin America. Still interested in educational gaming, he's further working to turn the audio navigation technology into a way to teach blind children topics such as anatomy (navigating a virtual human body Fantastic Voyage-style) and geometry so they can "start school at the same level as sighted" children, he says.

The top priority for the researchers, however, is to develop software that can create an audible map based on any provided floor plan. Merabet says he frequently receives requests from blind students who want a game based on their new university, or a mall in their hometown, so they can learn to navigate it before going there.

Online
sciencemag.org
Podcast interview
with author
Sara Reardon.

In all of the AbES iterations, Merabet says blind volunteers such as Buchanan are active consultants whose feedback is crucial. Recently, these volunteers began providing another type of feedback: images of their brain activity. For more than a decade, neuroscientists have studied the brains of sighted people as they've learned to navigate mazes or played video games inside MRI machines or PET scanners. Merabet is now studying whether the brain activity of blind people doing these puzzles differs.

As all of his subjects have been blind since birth, the visual cortex, which makes up 30% to 40% of the brain's cortical surface, has never received visual stimulation. In the past decade, however, researchers have found numerous ways that brains of the blind repurpose this "real estate:" the region is active when they read Braille, interpret language, and localize sounds, to name just a few.

The team has adapted AbES so that the subjects can play it inside an fMRI scanner. Given the previous data on brain-region repurposing, it wasn't a surprise to Merabet that the visual cortex of his blind subjects' brains was active during game playing. His team is now trying to dig up some more specifics. As a volunteer plays the game, the scanner records brain activity continuously. When the player encounters a monster or stops to figure out where he is in the maze, AbES time-stamps the event. This allows the researchers to determine exactly which parts of the brain are actively making navigation decisions at that point.

The researchers' early results suggest that at these junctures, sighted players generally use the memory center, the hippocampus, to remember where they are and decide what to do. But it is at these decision points that blind players' visual cortices activate most robustly. The researchers plan to test people who became blind late in life, to determine whether the adult brain's wiring is still malleable enough to use the visual cortex in this way.

The addictive nature of computer games has provided the researchers with willing test subjects. When he opens the fMRI scanner after a session, Merabet says he often finds the volunteers still playing AbES. "Just a few more minutes. I need to finish this level!" they plead, he says. The blind students at Carroll Center are even competing to see who can collect the most jewels, he has heard. "Blindness is so isolating," Buchanan explains. "Being able to play games, that's the best."

—SARA REARDON

EPIDEMIOLOGY

Outbreak Detectives Embrace The Genome Era

Doctors could soon be sequencing bacterial samples from virtually every patient. The avalanche of data will help fight disease outbreaks, scientists say

Ten years ago, the U.S. government embarked on an unprecedented effort in forensic science: sequencing an entire microbial genome. The push came just weeks after 9/11, when a series of anthrax-laced letters killed five people and spread terror on the East Coast. The FBI decided it was worth knowing the full-length sequence of the *Bacillus anthracis* strain used in the attacks—all of its 5.2 million base pairs.

At the time, the first anthrax genome project was under way; taking on another one was an extravaganza possible only because no expense was spared to solve the crime. "We literally had more money than God to throw at this problem," says microbial geneticist Paul Keim of Northern Arizona University in Flagstaff, enlisted as an expert by the FBI. The sequencing alone cost about half a million dollars, Keim says. (The effort led investigators to a flask at an Army lab that the FBI says was the most likely source of the strain.)



DNA sleuths. The sequencing of anthrax bacteria from the 2001 mail attacks was a first in forensic science

Since then, the cost of sequencing an anthrax genome has come down by three orders of magnitude, to under \$500. Sequencing machines are becoming ever faster, smaller, and cheaper—spreading beyond big centers into clinics and small labs. And now, Keim and other genomic epidemiologists say, it's time to use the technique to track microbial movements on a global scale.

By routinely sequencing bacterial samples—perhaps up to a billion a year—scientists could pinpoint the sources of new outbreaks faster, determine whether a bug is

resistant to antibiotics, and investigate how public policies or the use of certain drugs change the course of microbial evolution.

Four weeks ago, 25 scientists gathered in Brussels for 2 days to discuss how to mobilize such a massive effort and dream about the benefits it would offer. Participants concluded that the world needs a global system to share and mine genomic data for microorganisms. It could be operational in 5 to 10 years, they say—but there are some formidable obstacles.

Really scary outbreak

Currently, many U.S. and European labs use pulsed-field gel electrophoresis to identify strains of bacteria. In that system, microbial genomes are cut up by various restriction enzymes and separated on a gel. Scientists then estimate the size of the fragments and use the pattern to fingerprint a particular strain. But technology has moved on: "Imagine what kind of phone or computer you were using 15 years ago, and that is where pulsed-field gel technology is," Keim says.

Whole-genome sequencing can give better, faster answers about organisms, says Jørgen Schlundt of the Center for Genomic Epidemiology (CGE) at the Danish Technical University in Copenhagen, who organized the meeting. In January 2010, for example, scientists at the Wellcome Trust Sanger Institute in Hinxton, U.K., showed that by sequencing and comparing genomes of methicillin-resistant *Staphylococcus aureus*, they could track the global spread of the dangerous pathogen, document its likely emergence in Europe in the 1960s, and follow its spread within one Thai hospital.

In some cases, the genome can already deliver information in real time, as a threat emerges. When a deadly outbreak of enterohemorrhagic *Escherichia coli* hit northern Germany earlier this year, a group led by Dag Harsmen at the Münster University Clinic in Germany and another team at the Beijing Genomics Institute in Shenzhen, China, sequenced the strain responsible within days. The data gave scientists insights into the natural history of the *E. coli* strain and partly explained its virulence, but doctors battling the epidemic weren't helped much.

CREDIT: NEWS.COM

Downloaded from www.sciencemag.org on September 29, 2011