SCIENTIFIC AMERICAN FRONTIERS PROGRAM #1509 "Cybersenses"

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Every Sound a Present
Second Sight

ALAN ALDA Hello and welcome to Scientific American Frontiers. I'm Alan Alda. For those millions of us whose vision or hearing isn't perfect, there are glasses and hearing aids. But for those hundreds of thousands who are blind or profoundly deaf, devices that merely assist the eyes and ears just aren't enough. What they need are alternative routes by which the sights and sounds of the world can enter the brain and be interpreted. In tonight's program we'll see how the astonishing success of what are in effect artificial ears is not only changing the lives of many in the deaf community — especially the young — but is also inspiring researchers tackling the much larger challenge of artificial vision.

ALAN ALDA (NARRATION) We'll see a young girl hear her first sounds from a synthetic ear…

ALAN ALDA What kind of a star do you want to be?

ALAN ALDA (NARRATION) And catch up with her three years later.

KELLEY FLYNN I want to be an actress.

ALAN ALDA (NARRATION) And we'll meet a man whose artificial retina is giving him the first glimmering of sight.

ALAN ALDA That's my forehead. That's my forehead!

TERRY BYLAND Well, it's very bright, I tell you.

ALAN ALDA That's all coming up in tonight's episode, Cybersenses.

EVERY SOUND A PRESENT

ALAN ALDA (NARRATION) Three years ago we met Kelley Flynn, who lives with her family near Northampton Massachusetts. Kelley was then seven — and one of her favorite walks — then and now — is through the woods to a nearby river.

KELLEY FLYNN I love the river.

MARY FLYNN Why?

KELLEY FLYNN Because it is beautiful.

MARY FLYNN Yeah. Can you hear it?

KELLEY FLYNN A little.

MARY FLYNN What about when you get your cochlear implant?

KELLEY FLYNN When I get cochlear implant, I will hear the best.

ALAN ALDA (NARRATION) Kelley had been profoundly deaf since she was two. What little hearing she had -- boosted by a conventional hearing aid — was worsening. She had no trouble communicating by sign — but for years she'd wanted to talk.

MARY FLYNN Do you like to sign or do you like to talk?

KELLEY FLYNN I like to talk. That's why I want cochlear implant. To hear better.

MARY FLYNN To hear better. Why do you want to hear more?

KELLEY FLYNN Because I would love to hear more. Because when you call me, I will hear.

ALAN ALDA (NARRATION) Tomorrow is the day Kelley has been waiting for for months.

MARY FLYNN You're gonna go in, in the room, in one minute. Mommy has to change her clothes, and then I will go in there with you. Okay?

GARY FLYNN It's just the beginning, but it's an exciting beginning. And in a way, the beginning of her hearing in a whole new way which is very exciting. And she's the most excited about it.

MARY FLYNN Good girl, Kel. You're so brave.

ALAN ALDA (NARRATION) The surgery that's about to begin on Kelley will permanently implant a tiny set of electrodes deep within her inner ear. MARY FLYNN Thank you.

ALAN ALDA (NARRATION) In a normal ear, sound vibrations are translated into nerve impulses by millions of tiny hair cells lining the inner wall of the snail-shaped cochlea. Kelley went deaf when an infection destroyed these delicate hairs. A cochlear implant substitutes an array of tiny electrodes — 22 in Kelley's case — for the hairs of the hair cells, directly stimulating the cells to send their messages to the brain. Kelley's surgery is being done at Boston's Children's Hospital by Dr Margaret Kenna.

MARGARET KENNA What I'm doing now is drilling actually into the cochlear. And the bone of the cochlear is very hard bone -- harder than the rest of the bone in the rest of the body. And as you go towards the center of the cochlear it gets very white. So now we have a hole in the cochlear. Do you see it? ALAN ALDA Oh yeah, I see it very clearly.

ALAN ALDA (NARRATION) The electrode array being slipped into Kelley's cochlea is attached to a receiver that is also implanted under the scalp. Both the electrodes and the receiver are connected in turn to an antenna and a magnet. The entire implanted system is visible in an X-ray taken while Kelley is still in the operating room.

MARGARET KENNA This is the antenna right here. This is the magnet. This is the receiver stimulator right here. And this is the wires, the electrodes in the cochlear. If you look even closely, you can almost count each individual electrode.

ALAN ALDA (NARRATION) It will take about two weeks for Kelley to recover from her surgery.

MARILYN NEAULT Hi. Are you ready?

KELLEY FLYNN Yes.

MARILYN NEAULT Good. What are we doing today?

KELLEY FLYNN My cochlear implant will turn on.

MARILYN NEAULT We're turning on your cochlear implant. Alright.

ALAN ALDA (NARRATION) A wireless transmitter sticks to the magnet under Kelley's scalp.

MARILYN NEAULT Can you see it?

ALAN ALDA (NARRATION) From now on, this is how sounds will get to her brain — from the microphone behind her ear, via a computer that will process the sound into the signals sent to her cochlea. Right now, Kelley's microphone isn't on. These beeps are being fed into her cochlea directly. The cochlea normally responds to high frequency sounds at one end, low frequencies at the other. The electrodes in the implant mimic this process. Kelley has been asked to put a ring on the stick whenever she detects a sound.

GARY FLYNN She told her friend that when she came back maybe she'd be able to call her on the telephone. She's already exploring it in her mind. She's imagining the things she might be able to do. And her hearing, it's a gift now. It's not just being something you're born with. It's something very special to her. It's like Christmas. Each sound is a present.

ALAN ALDA (NARRATION) So far today, Kelley has only heard the beeps generated by Marilyn's computer. But now comes the moment Kelley has been waiting for. Her microphone is switched on. Now sounds from the room are able to enter her head.

MARY FLYNN Do you like the way that sounds? Is it really really loud? Is it really loud? Or is it perfect?

KELLEY FLYNN It's perfect.

ALAN ALDA (NARRATION) Kelley gets her own little computer to process the sounds picked up by the microphone behind her ear into the signals sent to her cochlea.

MARILYN NEAULT I'll just put it there. And let the hair fall down over it. ALAN ALDA (NARRATION) It's the sophistication of this processing — especially for the sounds of speech — that has in the last few years started to open up the hearing world to profoundly deaf children.

ALAN ALDA Hello. Hi. Hi.

ALAN ALDA (NARRATION) To find out how -- and what lies ahead for Kelley -- we're visiting a classroom for hearing impaired children -- where my job is to read a story.

ALAN ALDA "It isn't fair that my brother Anthony has two dollars and three quarters and one dime and seven nickels and eighteen pennies."

ALAN ALDA (NARRATION) The room is equipped with a sound system so that the voice of teachers — or guests — is kept at a constant level. Some of the

children here have conventional hearing aids. Several — including six-year-old Timmy — have cochlear implants.

ALAN ALDA Timmy, do you like money?

TIMMY I like lots and lots of money.

ALAN ALDA Lots and lots of money?

ALAN ALDA (NARRATION) Those of us without cochlear implants can never know exactly how they sound to children like Timmy, but here's a guess.

ALAN ALDA "So they brought lox because my father likes to eat lox, and they brought plants because my mother likes to grow plants."

ALAN ALDA (NARRATION) Like the children in the classroom, Kelley now faced many hours of hard work, both to decipher the sounds created by her cochlear implant and — even tougher — learning how to speak herself, after years of having few clues as to how her speech should sound. Meanwhile, she can finally hear her river. Three years after her implant, we met with Kelley again, along with Marilyn Neault, who first turned on her hearing.

ALAN ALDA Do you remember the day we were filming and your cochlear implant device got turned on for the first time?

KELLEY FLYNN Yeah. ALAN ALDA What was that like?

KELLEY FLYNN I wasn't camera shy at all. I felt like a star like I always wanted to be.

ALAN ALDA What kind of a star do you want to be?

KELLEY FLYNN I want to be an actress.

ALAN ALDA Yeah. Has Kelley already become a star from this program? Do people know her, know her face and everything?

MARILYN NEAULT Well, for the first couple of years, and it's been three years now, you would come and sit in our waiting room, waiting for an appointment with me, and families would come up to you and say, "You're the girl who was on the Alan Alda show, you were on Scientific American Frontiers. And they would tell you and your parents that the show had a big effect on them, it gave them confidence to get a cochlear implant for their child.

ALAN ALDA That's really great. You know what's great, better than being a star is being able to help people like that. I think that's terrific. How young can a child be and get a cochlear implant?

MARILYN NEAULT That's an interesting question. The Food and Drug Administration approves cochlear implantation beginning at age 12 months. ALAN ALDA What difference does that have on their ability to speak?

MARILYN NEAULT We used to be thrilled if a deaf child developed six month's worth of language in a year's time. And now we see them develop a year's worth of language in a year's time, or sometimes more. And we see two- and three-year-olds who have had their implant for a year or two who have spoken language development that's really within the normal range. They don't have to be behind any more. It's changed everything.

ALAN ALDA Does Kelley speak differently now that she has the cochlear implant?

GARY FLYNN I can remember after the implant, picking her up at Clark School probably six months after the implant, and she had gone on a field trip to Plymouth. And I was always very familiar — I shouldn't say this — driving with my knee and signing to her in the car and then getting that from her. This time it was dark and suddenly we were talking about — talking — about the field trip. And it was, it was….kind of gives me goose bumps now because it was a conversation in a way we never could have had before. ALAN ALDA Can you hear that plane?

KELLEY FLYNN I hear lots of planes during softball. And when my coach is talking, when he's telling us what you do, I keep hearing planes go by. Like yesterday, yeah, and all I could see…….like there's a bee in their mouth. ALAN ALDA Ah, that's good!

SECOND SIGHT

ALAN ALDA (NARRATION) We're in Los Angeles, where Terry Byland — who's been blind for the last eleven years — is about to see again. It won't be much — at best a few fuzzy blobs. But he and a team here at the University of Southern California Medical Center are hoping he's taking the first steps toward a device that could do in the future for the blind what the cochlear implant can do today for the deaf. Terry has retinitis pigmentosa, one of the main causes of blindness, affecting one in 4000 people. RP is an inherited degenerative disease — and it robbed Terry not only of his sight eleven years ago, but also, at the time, of his spirit.

TERRY That first couple of months was like hell for me. I didn't know what to do with myself. I couldn't do anything, I was so negative. And then I found out about the Braille Institute in Anaheim and going there they taught me how to be the best blind person I could be. So that's what I had to settle for. But now I realize, thanks to all these wonderful people here, I don't have to settle for that anymore.

ALAN ALDA (NARRATION) Six months ago, Terry was on the operating table for an eight-hour procedure performed by USC Medical Center's Mark Humayun, who implanted into Terry's right eye a tiny array of 16 electrodes less than a quarter inch square. Today, he's back for a routine check to make sure the electrodes are still sitting snugly against the retina — which in Terry's eye has the characteristically sooty appearance of retinitis pigmentosa. The electrode array is connected by a thin wire that runs just under the skin of his temple to a magnetic connector over his ear, very similar to the one used by Kelley and other cochlear implant patients. A tiny video camera transmits images to a computer, which processes the images and transmits them wirelessly through the magnetic connector and on to the electrode array. There the electrodes send the image in the form of electrical impulses directly to the optical nerve. In effect the 16 electrodes in the array function as a very crude, simplified substitute for the millions of light-sensitive retinal cells that in Terry's eye are damaged beyond repair.

ALAN ALDA When each one of these electrodes is activated, he's going to see either a dark spot or a light spot there? MARK HUMAYUN Well, that's the very interesting and intriguing thing. It turns out that when we activate one of these electrodes, it's very low current, initially most patients see a black spot. But as you turn up the current, that turns into a white spot. So the idea is to use each of these much like a dot matrix printer or the lights of a scoreboard, to light them to enable Terry to be able to recognize shapes.

ALAN ALDA OK, I'm rally anxious to see what he sees.

ALAN ALDA (NARRATION) The video camera that's will act as Terry's eye is in the bridge of the glasses.

MARK HUMAYUN OK, and I'll give you the connector here.

TERRY BYLAND OK.

MARK HUMAYUN Just to show that it's very easy for the patient to do this.

ALAN ALDA (NARRATION) Today's test is to see if Terry can locate a light square projected on to the wall. Because the video camera is in his glasses, to move his field of vision he has to scan with his head.

TERRY BYLAND That would be upper left.

MARK HUMAYUN OK, good. And what we do is we also time it.

ARUP Ready Terry?

TERRY BYLAND Yup. That would be lower left.

MARK HUMAYUN Good, that's very good. Terry, you're getting very good at this.

ALAN ALDA What are you actually perceiving, Terry?

TERRY BYLAND Well, it's a light light, and it's actually fuzzy looking, and it kind of flickers… a white flickering fuzzy light, and it's about this big around. After being blind for eleven years it's so wonderful to be seeing any of this stuff. For some people who have never lost their sight it may not be a big deal, but for us it's just amazing.

ALAN ALDA (NARRATION) Terry did well locating the squares. But now he has to scan carefully so that the electrode array on his retina will reveal if the bar is vertical or horizontal.

TERRY BYLAND That's a vertical.

MARK HUMAYUN Correct.

ALAN ALDA Seven seconds. I don't mean to rush you. I get competitive about this.

TERRY BYLAND They're always telling me to slow down.

ALAN ALDA (NARRATION) So far, Terry has only used the device in this room, scanning images like these for a few hours at a time — and it's still hard for him to figure them out.

TERRY BYLAND That would be vertical again.

ALAN ALDA (NARRATION) The computer screen allows us to see how the electrodes are being activated as Terry scans the shapes.

ALAN ALDA I think I know what it is now. Do you know what it is?

TERRY BYLAND Looks like vertical again.

ALAN ALDA To me too, yeah.

MARK HUMAYUN OK, both of you are correct.

ALAN ALDA Am I seeing it more clearly do you think than Terry is seeing it? I mean, I'm seeing distinct dots, you know.

MARK HUMAYUN That's an important feature, because there's going to be some current spread from the electrodes. So the perceptions are going to blend a little bit. So you're seeing it much, you're probably seeing it clearer than what Terry sees.

ALAN ALDA I see.

ALAN ALDA (NARRATION) Not only do the nice clean dots we can see appear much fuzzier to Terry, but the part of his brain receiving those fuzzy images hasn't been getting input from his eyes for eleven years now.

TERRY BYLAND That'd be horizontal.

ALAN ALDA See, I got you rushing.

MARK HUMAYUN What you see is that there may be some reorganization, some learning that needs to be done in an area that hasn't seen for a while.

ALAN ALDA You bring up a really good point. Because even though this is more distinct than what Terry is seeing, I'm able to interpret these dots more easily than probably Terry can without practice.

MARK HUMAYUN If your arm has been in a sling and you haven't used it for a while and someone asks you to write, your initial writing is very different. ALAN ALDA Have you seen any objects in this setting or have you only looked at these rectangles of light so far?

TERRY BYLAND It's all been in this room so far, mostly of the light variety, we haven't been outside yet.

ALAN ALDA Because I'm wondering, if you see for the first time someone you know, your wife or your child, even though they're just a blob, I wonder what effect it will have on you?

TERRY BYLAND It'll be wonderful, I'll tell you. It'll be really wonderful. It's been a long time.

ALAN ALDA (NARRATION) These goggles will give me a sense of the 16 pixel world Terry might see once he leaves the testing room — though my pixels are much sharper than the fuzzy blobs Terry reports seeing.

ALAN ALDA Let me spin around a little bit. Am I driving you crazy? Let's see here, pretty dark. There's the camera, kind of dark. But I'm just seeing squares of light and dark.

MARK HUMAYUN Can you tell which way my hand moves?

ALAN ALDA Left and right.

MARK HUMAYUN Right. That's a tremendous improvement for somebody who is completely blind, to be able to tell motion.

ALAN ALDA (NARRATION) The next generation of the artificial retina will have 64 pixels rather than 16.

MARK HUMAYUN This is the generation we're talking about launching in the middle of 2005.

ALAN ALDA OK. Sort of a head and shoulder shape. Somebody just came in.

TERRY BYLAND Can you see any movement over here Alan?

ALAN ALDA Yes, yes, I can see on my upper left.

ALAN ALDA (NARRATION) But the 64-pixel array is only the next step toward what Mark Humayun hopes will be a system that goes far beyond being able to provide glimpses of shapes and movement.

MARK HUMAYUN This is going to be, we think, the significant jump.

ALAN ALDA How many pixels will this be?

MARK HUMAYUN This will be 32 by 32, or about 1024.

ALAN ALDA Wow. Oh, oh my god. Terry, Terry, this is going to… you're going to be amazed at this. Here's what I see. I see clearly head and shoulders. I see the painting behind you. I see three squares that are your nose, the shadow of your nose. I see two squares that are our eyes. I see your cheeks. I actually see a face.

TERRY BYLAND Oh my god.

ALAN ALDA Let me see you smile. Can I see you smile? Yeah, I can't quite pick up the smile. But a little it, a little bit. Yeah I think I can. Oh god, Terry, you're going to love this.

ALAN ALDA (NARRATION) One of the hopes for a 1000 electrode artificial retina is that it will allow people to read — at least large print.

ALAN ALDA Wait. "The Retina Institute."

ALAN ALDA (NARRATION) But remember, I'm using a only a simulation of a thousand pixel array — and as we've seen from Terry's testing, it's much harder for him to make sense of the fuzzy blobs he sees than the perfect little squares projected into my eyes. But for Terry and the thousands like him with incurable retinal blindness, there is now hope for the first time.

ALAN ALDA With practice, you're going to be able now in the next few months with just 16 pixels to be able to sense things and see things that you haven't been able to see before. When you get this… this is amazing.

TERRY BYLAND Oh it is. It's just going to get better and better, that's why it's so exciting to be part of it even on a daily basis.

ALAN ALDA (NARRATION) At the end of our visit to the USC Medical Center we persuaded the researchers to let Terry try the system outside for the first time. In the coming months, the plan is to let him take it home and use it daily with the hope that he'll gradually piece together a very primitive picture of the world around him.

ALAN ALDA How about, if you look down, down to about there, from there to there, do you see any difference in light?

TERRY BYLAND Right there is shade. Up there is light.

ALAN ALDA Right. Let me point…

ALAN ALDA (NARRATION) In the eleven years since Terry lost his sight, like many blind people he has learned to sense his environment from other cues — especially sound, like that of the water behind us.

ALAN ALDA You're accustomed to listening to sounds and knowing how close you are. And now you're adding light and dark. So I'm wondering if…

TERRY BYLAND That's real light right there.

ALAN ALDA That's my forehead. That's my forehead!

TERRY BYLAND Well, it's very bright, I tell you.

ALAN ALDA That's great.

TERRY BYLAND Very bright. Very bright. Oh god, this is beautiful, I tell you.

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