



#206: Bionic eyes: Emerging technologies in the battle to restore vision

VOICEOVER

Welcome to Up Close, the research talk show from the University of Melbourne, Australia.

SHANE HUNTINGTON

I'm Shane Huntington. Thanks for joining us. Visual impairment can take many forms, and can be caused by a range of conditions. In mild form, it can be corrected with glasses, contact lenses, or in some cases, routine surgery. Unfortunately, solutions are not available in many cases, and those afflicted are left without any vision at all. Enter the potential of the bionic eye - a concept and technology now being researched in different forms worldwide. The basic idea is to supplement the body's normal functions with an artificial, electronic implant. Many people are now familiar with the cochlear implant, which is a bionic device that has restored hearing and changed the life experiences of hundreds and thousands of people, young and old. The hope with the bionic eye is that an even more profound impact will result, enabling new levels of functioning to the blind. Today on Up Close, we are joined on this topic by researcher and optometrist, Dr Lauren Ayton. Lauren is the clinical research coordinator at the Centre for Eye Research Australia. Welcome to Up Close, Lauren.

LAUREN AYTON

Thank you, Shane.

SHANE HUNTINGTON

If we were to look at the eye in sections, what are the different types of blindness that we see in the community, and what sections of the eye causes them?

LAUREN AYTON

That's a very good question, Shane. So, the eye and vision is a very complex system. So, for someone to see something, light actually comes in through the front of the eye, and then is focused at the back of the eye. So, going from front to back, the front tissue of the eye is called the cornea - so, people can have opacities and problems with the cornea, which block the light from going through. As you were mentioning just before in the introduction, with a corneal opacity, we can actually do surgery to fix that. So, we can take the cornea off and put a replacement cornea on the front, and then obviously help that problem. If you keep moving back in the eye, the next part that the light gets to is called the lens of the eye, and it's like the lens inside a camera, so it actually focuses the light. The lens is the most common part of the eye that's affected by disease, and that's a disease called cataracts, which actually happen to everyone if you get old enough, so it's actually an aging process. And what happens is that the lens changes colour, and becomes less transparent to light. Again, cataracts are treated with surgery, so the surgeon will actually take that lens out, and put another lens in to replace it. When you get further back in the eye, it gets a lot more complicated. So, the next part of the eye where the light hits is called the retina, and that's kind of like the

film in a camera; so, that's where the light is translated from light into an electrical signal for the brain to interpret. When there are problems with the retina, obviously we can't just take the retina out and put a new one in. It's way too complicated for that, and that's when, unfortunately, often, we don't have treatments. So, there's a number of different retinal diseases; things like age-related macular degeneration is a very common retinal disease where we can actually stop the progress of some of those disease mechanisms by using drugs injected into the eye. But unfortunately, for a lot of retinal disease, there is no treatment at the moment.

SHANE HUNTINGTON

So, Lauren, given these various parts of the eye and the diseases that we get, who would be benefitting from the development of a bionic eye?

LAUREN AYTON

So, there are actually a number of different types of bionic eye devices. The one that we're working on with Bionic Vision Australia is called a retinal prosthesis. The aim of it is to replace the function of this retina or film at the back of the eye, and so we're really targeting people that have retinal eye disease. In particular, there are two conditions we're focusing on; one that's called Retinitis Pigmentosa, or RP - and RP is actually the most common hereditary retinal disease. Quite debilitating, it actually affects people in their childhood or early teens, and it's degenerative, so it leads to total blindness. The other condition that we're looking at is age-related macular degeneration, and that's - as the name suggests - it's something that affects people sort of once they're over the age of 60 or 70, and affects their central vision.

SHANE HUNTINGTON

What sort of effects would a person with one of these conditions have in their visual field?

LAUREN AYTON

Yes, so they're quite different in terms of what people actually experience. Retinitis Pigmentosa is the one that people most associate with tunnel vision. So, these people actually lose their peripheral vision first, and it slowly progresses in. People describe it like looking through a straw, so it's a very constricted field. And then, if the disease continues from there, then they lose all their vision and are not able to see anything. With age-related macular degeneration, it's actually almost the opposite, so it affects their central vision. So, they lose the ability to read or to see people's faces, but their peripheral vision is still available to them. So, as you can imagine, they are quite different ways of looking around the world. People with age-related macular degeneration can actually still walk around quite well and see objects, but they're losing that fine central vision.

SHANE HUNTINGTON

If a person is born blind or has other forms of blindness, perhaps caused by car accidents or other incidents in their life, is the bionic eye not useful for them in terms of getting their vision back?

LAUREN AYTON

There's probably two bits to that question that I'll answer separately - so, one being if it's another cause of blindness, so obviously trauma is a very big one. Especially with a lot of our armed conflicts around the world, and wars, a lot of people are blinded from those sorts of issues. Unfortunately, with our implant, with a retinal implant, it won't help those people, but there are other bionic eye devices around the world that might. So, some of the devices actually go straight to the brain and they are called a cortical implant, and they can actually help people that have different types of vision loss. With the cortical implant, it is quite different in terms of the vision processing and things, so there are, I guess, pros and cons to both issues.

So, the second part of your question related to congenital blindness and children that are actually born blind - this is quite a complicated issue, because the visual system actually needs experience to develop properly. So, for those of you at home who have children or have seen babies grow up, you'll notice that when they're very young, they don't tend to follow us very well, and as they get older, they start to track and start to watch where Mum's face is, and then start to show more interest in things like toys. So, that process as their vision develops is really led by what they see, so obviously a child that is born blind isn't going to have that vision development. And what happens is that the optic nerve and the visual cortex don't develop as they should, so that's very complicated. If we then want to use electrical stimulation of the retina to give them some vision, unfortunately the optic nerve and the brain won't have developed as they should. It's something that we are hoping that, in the future, might be worked on, but it is going to be quite a challenge.

SHANE HUNTINGTON

Lauren, what does this device actually look like, that you are working on?

LAUREN AYTON

Our real aim is to try and make it look as normal as possible. One person I spoke to a few years ago made the mention that they didn't want to look like a monster, and we agree with that. So, the idea, really, is to have a pair of sunglasses, which have a camera on the front, and so the camera will basically film whatever they are looking at. Then, the image from the camera is sent back to an external processing unit, which changes that video image into electrical stimulation. The actual electrodes that stimulate the eye go into the back of the eye behind the retina, and so they'll actually be implanted during a surgical procedure.

SHANE HUNTINGTON

What's the device made of?

LAUREN AYTON

There's quite a few components to it. So, the internal parts that are put inside the eye are mainly made from things like platinum and silicon, and these are all materials that have been shown to be very safe and biocompatible with the body. We are actually working on another implant as well, so we're looking at two different types of implants, and our second implant we're looking at has also got diamond in it. So, it's actually a box encapsulated by diamond - so, again, another material which has been shown to be biocompatible, and obviously very strong.

SHANE HUNTINGTON

Now, there are many different research groups around the world working on bionic eyes, and have been for many years. What other methodologies and approaches are being taken by some of these groups that are of interest?

LAUREN AYTON

Yes. So, one of the easiest ways to think about the way that visual prostheses can work is to think about the visual pathway - so, to think about, when you're looking at something, when we look at an object, we're actually looking at the light reflected back from that object - so, going through the eye back to the retina at the back of the eye. The image is then translated along the optic nerve, and it goes back to the brain. So, different research groups are looking at different locations along that pathway, to stimulate. So, obviously, the group I work with, Bionic Vision Australia, are looking at retinal implants. There are some groups around the world that look at stimulating the optic nerve itself, and they actually do that with what's called a cuff electrode, which wraps around the optic nerve. Then, there's groups that look at stimulating the brain

directly as well.

SHANE HUNTINGTON

This is Up Close, coming to you from the University of Melbourne, Australia. I'm Shane Huntington, and in this episode, we're talking about the promise of the bionic eye with Dr Lauren Ayton. Lauren, let's talk about the device and how it actually works. Can you walk us through this, from the point of detection of light by the sunglasses, or the glasses worn by the patient, to the point where they are actually perceiving something?

LAUREN AYTON

So, the idea is that the video image from the camera is actually translated into the stimulation parameters, using quite complex computer programming. And the signal is then sent from that external processing device into the electrodes. The electrode arrays is a piece of silicon with some electrodes on top of that, and what the electrodes do is actually send out an electrical signal to the retina. The conditions that we're looking at - so, this Retinitis Pigmentosa and age-related macular degeneration - they actually only damage one layer of the retina. So, all of the sort of cables and wires and the inner neurons are relatively intact. The idea behind a retinal visual prosthesis is that you can use electrical stimulation to actually stimulate the nerves that are left in the eye itself, and then to stimulate the optic nerve; so, the idea is, keeping it as natural as possible.

SHANE HUNTINGTON

How do you know what type of electrical stimulation to apply to these regions? I mean, my guess here is that we're talking about very, very small current signals.

LAUREN AYTON

It's a very good question. So, there's obviously a number of ways that we look at these things; a lot of computer modelling, to work out what we think the estimated thresholds will be for a retina. We have got some data from some of the groups overseas as well, so we can get an idea of what sort of levels of stimulation we will expect, but as you can imagine, it will be quite a slow process at first, testing very slowly to find the levels that are safe for stimulation, and effective.

SHANE HUNTINGTON

What sort of image will the recipient of one of these devices actually get?

LAUREN AYTON

This is one of my favourite questions. People tend to think about actually someone seeing like a video - just seeing like a normal movie. Unfortunately, it won't be like that at all. So, what the electrodes will do - because they are small circle-shaped electrodes at the back of the eye - they are going to stimulate, so that people can see small spots of light, what we call phosphenes. The easiest way to think about phosphenes, if you are listening at home, is to actually close your eyes and just gently press on your eyelid. When you do that, what it actually does is, it causes mechanical stimulation of the photoreceptors at the back of the eye, and it will let you see these phosphenes or spots of light. So, we're going to try and stimulate those little dots of light for people that are blind, and the idea is to really help them with things like object identification. So, if you couldn't see anything at all, but then you had some spots of light to let you see the edge of a table, or where the window is, or the door, that's obviously going to be quite helpful.

SHANE HUNTINGTON

Right. Why is it that we can't improve the resolution of this device to give more than these phosphenes in

terms of a response, given the high density with which we can lay down these receivers of optical information in things like cameras?

LAUREN AYTON

It has basically got two issues with that. One is that we're limited by the size of the actual electrodes themselves; so, obviously manufacturing the electrodes, there's certain limits within that. Then, also, we need to be careful about the charge of the electrodes and the electrical current as well. So, going small can have implications for the electrical stimulation. But probably, the more pertinent thing is that the retina itself is an extremely complicated tissue. So, to give you an idea, in the retina, the photoreceptors are like the cells that respond to the light. There are two types of photoreceptors; so, there's cones, that respond more heavily to light and daytime stimulation, and then there's the rods, which are more useful for us during nighttime. There are about seven million cones, and around about 75 to 150 million rods. So, trying to replicate that complexity with an electrode is very difficult.

SHANE HUNTINGTON

Many of our listeners would be aware of the mega-pixels that their cameras have. How does that number relate to the electrodes and so forth in the devices that you're putting in the eye? What is the sort of equivalent number of mega-pixels that these devices will have?

LAUREN AYTON

It's a little bit complicated to sort of consider mega-pixels and electrode numbers. Because of the processing that occurs in the retina, it's kind of hard to directly link the two. So, what we have done is, done a lot of looking at computer modelling of how many electrodes we would need to give people back a good level of vision. One of the most promising papers came out I think around 2009, and looked at, if you wanted to give someone enough vision to be able to read a book or to recognise faces, we would probably need around about 1,500 electrodes in the array. If you actually wanted to get even finer detail than that, then you'd be looking at around tens of thousands of electrodes - so, quite complicated in a manufacturing manner. Unfortunately, it's a bit hard to sort of think about it in terms of mega-pixels, just because of the retina's action.

SHANE HUNTINGTON

Now, with something like the cochlear implant, the bionic ear, there is a period of learning where the recipient has to essentially learn how to hear. In fact, in some cases, they've never heard before, and often they are put into children because that adaptability is so high in children. Is it going to be similar for the bionic eye, or is this something that you just switch on and it works?

LAUREN AYTON

We actually think it might even be more complicated with the eye, to be honest. Vision is a very complicated sense that requires a lot of things to go right, and so we think it will be quite a lot of training. The experience that people overseas have had - there's a group in the United States called Second Sight, who have done some implants with people - and they were finding that it was taking up to two years to teach people how to actually use the device to see objects. And so, obviously rehabilitation and training is very, very important for us. Your point about the cochlear implants in children is a really good one as well. What we're finding with vision is, it's a little bit different, in that, if a child is born blind and they don't have any vision as a young child, they actually don't tend to have development of the visual system, and they can get what's called amblyopia, or basically, sort of lazy eye. We think that that will be quite a complicating factor for bionic eyes, and that, at this stage, it would be a big challenge to give a bionic eye to a child.

SHANE HUNTINGTON

I'm Shane Huntington, and my guest today is Dr Lauren Ayton. We're talking about the design and construction of bionic eyes, here on Up Close, coming to you from the University of Melbourne, Australia.

We know, today, Lauren, that the brain has an incredible level of plasticity - something we've learned over the last two decades. It can adapt to damage and problems, and essentially rewire itself as needed. Does this occur when people lose their sight as well?

LAUREN AYTON

Yes. It's something that definitely does happen, and it's something that we are really, to some extent, relying on a little bit with this invention. So, one of the ways that we can see plasticity in the visual system is - especially in children, I was mentioning before about amblyopia or lazy eyes. When we are working with children that have a problem with one eye, we can actually patch the other eye to help their vision system in the damaged eye to recover. This has been shown to also happen in adults as well. It's not quite as fast - it takes a little bit more time for that rehabilitation to happen and the neuroplasticity. But we do think that it will happen, and that will help people use this bionic vision.

SHANE HUNTINGTON

In terms of the plasticity and how it enhances the performance, you talked about not using this in children. How much are you depending on an adult continuing to have that appropriate level of plasticity for the bionic eye to be effective?

LAUREN AYTON

We think it will definitely make a big increase in their performance. So, we think that, even if there wasn't much neuroplasticity, they still will have those spots of light and be able to make out the objects. The hope with the neuroplasticity is that it will then improve that even further, and help them to sort of make more sense of the spots of light. Neuroplasticity is really a big part of all this vision rehabilitation research.

There's actually a study that was done in around 2010, looking at actually using stimulation of the tongue to give back people some sense of vision. So, what they did is actually used a tactile sensation - kind of like pressing down on the tongue - in shapes of letters, and then people were reporting that they could actually make out that letter, which is fascinating. But even more fascinating, they actually showed that there was then activity in the visual cortex; so, the vision part of the brain was actually responding to the tongue. And so, that was a very rapid change in the brain activity. It happened within a few months. So, if we can have something like that happen with electrical stimulation of the retina, it will definitely make a big difference to people's activities after implantation.

SHANE HUNTINGTON

Now, a project like this must involve an incredible range of different specialities. Who is involved thus far?

LAUREN AYTON

It's a huge project. We actually now have about 160 researchers within Bionic Vision Australia. So, we have five core partners - so, obviously the University of Melbourne, and the Centre for Eye Research Australia, which is the clinical arm of the project. We also have researchers at the University of New South Wales, and NICTA in Canberra, and the Bionic Institute as well, who were responsible for the cochlear implant development. So, we have a whole range of professions working towards this. Obviously, in the clinical arm, we have optometrists, ophthalmologists, surgeons, orientation and mobility specialists, occupational therapists - they are all interested in the vision and the rehabilitation. In terms of the device development, we have a huge team of material technicians, engineers, biomechanical engineers, that are working on how best to design the implant and what the best materials are, to do that.

SHANE HUNTINGTON

It's currently mid-2012. Where are we sitting in terms of the progress of the project? Have you started clinical trials?

LAUREN AYTON

No. So, we're hoping to start clinical trials next year. We have been doing a lot of work in my particular project looking at which people would be the most suitable for an implant like this. What we're trying to work out is, what's the best ocular parameters - so, what type of eye disease do we think might work best, what level of vision do they need to have, and obviously the device is progressing well, as well. So, we're hoping, next year, to begin testing with patients of this device.

SHANE HUNTINGTON

In terms of the device and where it attaches, or where the electrodes attach physically, how is that done?

LAUREN AYTON

So there are a number of different ways of using retinal visual prostheses. There are a couple of groups around the world that have been looking at what's called an epiretinal device. So, what they do for this is actually make an incision into the front of the eye, and they pop the electrode into the inside chamber of the eye and tack it onto the front of the electrode, almost like with a drawing pin - obviously, a little bit more technical than that. With our device, it's what's called a suprachoroidal device, and so what happens with our electrode is, it actually goes in behind the retina. So, when you look at someone's eye, the white part of the eye is what's called the sclera. It's a very tough, very rubbery tissue. So, what we want to do is actually slide our electrode in between that sclera and the more sensitive retina tissue inside. The advantage with that is that the retina and the sclera actually act to sandwich the electrode into position, so it won't move very much and it will be quite nice and stable. The other advantage is, because we're not actually going straight in the front of the eye into the inner chamber, we think it will be an easier process to actually remove the electrode from that inner pocket between the retina and the sclera.

SHANE HUNTINGTON

Is there any likelihood that the body will simply want to reject these particular devices?

LAUREN AYTON

We don't think that will happen, and there's a couple of reasons for that. One is that the materials that we're using are very biocompatible; so, the silicon and platinum have been shown to be very safe long-term. The other thing is that the retina is an immunoprivileged area, and so it doesn't tend to have rejection of things like that. Obviously, we've never really put electrodes into the retina before, so this will be something to be looked at, but it'd be very unlikely.

SHANE HUNTINGTON

Now, what are the technological barriers that are still to be overcome for this device?

LAUREN AYTON

The main technical challenge is probably going to be the issue of getting the number of electrodes that we would like into the back of the eye. So, the other complicating factor is that, obviously, we can make more electrodes onto an electrode array, but we have to be able to get that into the eye. And as you can imagine, the eye is a ball full of fluid, so if we make a cut that's too big in the side of that, it will deflate like a basketball. So, this is another factor that has become a bit of an issue. So, it's a matter of getting the number of electrodes that we like, and also the processing that will give people the best vision.

SHANE HUNTINGTON

Now, the bionic eye, to me, seems almost an option of last resort for people with these conditions. Is there other research going on to deal with these conditions, through medication, through surgery or other potential - you know, almost like a vaccine against getting these things, that may one day give people other possibilities?

LAUREN AYTON

Certainly, certainly. So, there's a number of different ways that we're looking at retinal diseases, so we are looking at things like gene therapy and stem cell transplants, to try and stop the progression of some of these genetic diseases. Probably the biggest success story with retinal disease is age-related macular degeneration. About ten years ago, it was a pretty poor prognosis if you got this AMD. What we now have is an injection that's called an anti-VEGF injection, which is anti-vascular endothelial growth factor. What we can do is inject that into an eye, and it actually stops new blood vessels from growing, and so that can actually stop the bleeding at the back of the eye, which causes blindness in age-related macular degeneration. A publication that came out in 2012 actually showed that, in some countries, it's halving the risk of blindness from age-related macular degeneration.

SHANE HUNTINGTON

Now, given all that - and you know I've just been given the bionic eye, and some of these new possibilities come about - will this be something that you'll be able to remove from the patient?

LAUREN AYTON

As you said before, with the bionic eye, it is for people that are end-stage. So, these people won't benefit from things like stem cells and gene therapy; they've already lost their vision. However, the removability of the implant is very important to us, and so one of the main advantages with the Bionic Vision Australia implant is that we're actually putting it behind the retina. So, the retina, as I mentioned before, is very complex. It actually has five main layers of cells, and what we're doing is actually putting it behind the entire tissue, and the hope with that is that we can then take that out and replace it, or remove it entirely if we wanted to.

SHANE HUNTINGTON

Dr Lauren Ayton from the Centre for Eye Research Australia, thank you for being our guest on Up Close today to talk about this amazing work towards the production of a bionic eye.

LAUREN AYTON

Thank you so much for the opportunity, Shane.

SHANE HUNTINGTON

Relevant links, a full transcript, and more info on this episode can be found on our website at www.upclose.unimelb.edu.au. Up Close is a production of the University of Melbourne, Australia. This episode was recorded on 4 July 2012. Our producers for this episode were Kelvin Param and Eric van Bommel. Associate Producer Dyani Lewis, Audio Engineer Gavin Nebauer. Up Close was created by Eric van Bommel and Kelvin Param. I'm Shane Huntington. Until next time, goodbye.

VOICEOVER

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