Sue Nelson
Hello, I'm Sue Nelson and welcome to the Create the Future podcast brought to you by the Queen Elizabeth Prize for Engineering, celebrating engineering visionaries, and inspiring creative minds.
[Music]
Today's guest is especially bright and not just because she combines medical physics and bioengineering. Clare Elwell is head of the BRIGHT project funded by the Bill and Melinda Gates Foundation. BRIGHT stands for brain imaging for global health, and it's investigating the effect of malnutrition on early brain development on children in The Gambia and the UK, a Professor of Medical Physics at the University College London's Faculty of Engineering Science, Clare is the director of the near-infrared spectroscopy research group in their Biomedical Optics Research Lab, she helped develop a non-invasive neuroimaging technology using light. It's called functional near-infrared spectroscopy, often shortened to fNIRS, and it measures blood flow and oxygenation in the brain. Welcome, Clare.

Clare Elwell
Great to be here Sue.

Sue Nelson
I thought we'd begin by actually finding out how this technology this near-infrared spectroscopy, fNIRS actually works.

Clare Elwell
The technology has often been referred to, I've spent my career working on a glorified torch. So it's pretty simple in concept. It relies upon the fact that we're very familiar with the idea that blood changes colour as the oxygen content in the blood changes. So most of us are familiar with the idea that blood that contains lots of oxygen, it’s bright red in colour looks a little bit like tomato ketchup, you know, these horror movies where you see this bright red blood squirting out. But when the blood is less oxygenated, when the oxygen has started to come out of the blood, it transfers colour to more of a blue purpley colour. So in essence, if we can measure the colour of blood, then we can work out how much oxygen it's carrying. So our technique shines light on the blood, to enable us to measure the colour of that blood. And so it's very easy to use light to measure colour. And if we can measure colour of the blood, then we can work out how much oxygen is in the blood. And if we can measure the colour of the blood all over the brain, we can work out where the oxygen is in the brain. The other trick that we use is we don't use normal white light, we use near infrared light. And that's because bone and particularly skull is transparent to that light, which means the light will pass nicely through the skull and actually get to the brain and the blood in the brain that we're interested in.

Sue Nelson
So what devices do you use, then that allows you to take this colourful picture of what's going on in the brain.

Clare Elwell
So we spent many years, in my experience three decades in honing the technology using the very latest light sources and light detectors. So we now use LED sources of a range of different wavelengths in the near infrared. So the near infrared is just beyond the visible. So we're using typically invisible light, and it's actually the type of light that would come out of your TV remote control. It's harmless, it's low energy, so it's not going to cause any damage to the tissue. And we can actually monitor the brain using these types of wavelengths for several hours, we're not going to cause any damage. It's a long way, for example, from ionising radiation, which is in a very different part of the electromagnetic spectrum that you would use for like X ray imaging. So we're not associated with any of the issues that you might have if you were using X ray. So yeah, we have very specific light sources that work at the wavelengths that we need to be able to penetrate the skull and look at

the colour of the blood. And then really highly sensitive light detectors. And we can position these, we develop helmets, where these light sources and detectors are embedded within the helmet. And then we can change the shape and size of the helmet to match the shape and size of the head that we're interested in. So there's been a lot of engineering in making sure that the headgear that we use is appropriate from birth all the way up to well, we do measure adults but in the BRIGHT projects up to five years of age.

Sue Nelson
When and how did you realise that this technique could be used and applied in this way?

Clare Elwell
Well, I actually joined the team at University College Hospital initially, I've always worked as a medical physicist, but I initially my first job was actually working on neonatal intensive care, working with clinical teams that look after premature babies. And they just started really investigating whether this technology could work in understanding infant brains. And the technique was originally described back in the 1970s. When a guy called Frans Jöbsis-vanderVlie, from Duke University in the States, he was actually sitting at dinner one evening, and he was trying to think of how he might be able to find out more about what's going on in tissue. And he held up a steak bone. And he saw the steak bone was almost transparent. And he took it into his lab and then held it in front of near infrared light. And then that made the bone completely transparent. And that was really his lightbulb moment in thinking, "Oh, okay, we can shine light into the brain". And the idea of spectroscopy, measuring the colour of something has obviously been around for a long, long time. So it was he that really put those two phenomena together. But it was really our team back in back in the 1990s, that really started to understand that this was, first of all, a very safe technology to use on infants, but also that was providing really invaluable information about just how the brain was using oxygen, how oxygen was being delivered. And that's really informative in understanding brain injury and helping the management, the clinical management at that time of young babies.

Sue Nelson
And was that the trickiest part for you, that managing that part of the technology?

Clare Elwell
We're moving through this real sort of game changing period of optics, because we're all walking around with cameras on our phone. So the detectors became much more available and much less expensive. And that's true with LEDs as well. So I mean, I can remember that it was highly unusual to get a blue LED on anything at all the LEDs were red. So all of those other areas have fed into the availability of hardware. So that side of it has been really, you know, tagging on to all of those innovations. I think for me, one of the exciting things and challenging things is how do we make sure that we can put all of this hardware safely on an infant's head, and essentially not have them realise that they're having their brain measured, because we want to measure these infants in the most naturalistic way that we can and we want to measure their behaviour, we want to measure their responses to the world around them. We don't want them to be massively distracted with what they may be wearing on their head. So we've worked really hard on developing materials that are very lightweight, bringing in designs that mean that their headgear is very well fitted and very lightweight, but mostly that it's movable with the infant as well, because we never sedate our infants. We can't get them to sit still. So all of our hardware has to move with the infant. So that was one of the major challenges in this project in the early days. The project that really led to the BRIGHT project, this project really started with us looking at infant brain development in four-month olds in an autism project. And right from the beginning of that project, I was working with the clinical psychologists that are used to doing infant measurements of behaviour, and getting to understand their environment getting to understand the infants. And we were given a really hard line by the head of their lab for good reason. She said "if we bring an infant in for you to study, you've got 30 seconds to

get the headgear on the head of the infant. And if if it takes longer than that, or the infant becomes upset, it's game over for your study". So that rather concentrates the mind in in saying, "right, we have to get this technology, right, we have to understand the end user, we have to understand the context in which our technology is being used". And I think that's a really good lesson for all engineering.

Sue Nelson
Absolutely. And I was quite interested in that project from a sort of personal perspective, as well as in that I only found out a few months ago, I had a diagnosis of autism. And obviously, it's something that I've had all along but nobody really identified. Even though the clues were all there hidden in plain sight, shall we say. So how does measuring blood flow, how does this brain imaging technique potentially identify a child who's likely to develop autism, what is this about their blood?

Clare Elwell
Yeah, so it's a good question. So if you're aware, you know, autism is diagnosed mostly by behavioural signs. And in infants, it's typically not diagnosed until the second or third year of life where the infant will go through a number of behavioural assessments. And the group that I was working with at Birkbeck, were interested in knowing whether there was any indicators much earlier in life in the way in which the babies were responding to different cues, particularly to social and non-social cues. And so we worked with them to build a device that enabled us to look at the oxygen distribution in babies brains as they were looking at different types of stimuli. Some of them social human images of an actress doing Itsy Bitsy Spider and doing various sort of hand gestures. And then we'd counterpose that with some images of tractors and helicopters and cars, so completely non-social, non-human images. And what we found was in a typical developing infant, they have a much greater response to the human and social images. That means that there's an increase in blood flow to certain regions of their brain and increase in oxygen delivery. And that tells us that the infant's responding to that image. When we studied infants who were at risk of autism, just four months of age, we saw virtually no difference in their response, that brain response to the social human images and the tractors and cars. And that was the first time anyone had been able to say, actually, as early as four months of age, we're seeing differences in these infants brain responses. And then we followed those infants that were at risk of autism up to three years of age, and showed that those infants that showed very different levels of or no difference in responses between the social and non-social images, were the infants that were most likely to be diagnosed as autistic from their behavioural signs at three years of age. The real goal here is to be able to feed that information back and potentially start interventions, you know, to potentially help that infant in understanding the social world around them, much earlier than you might do if you're just relying on a diagnosis at three years of life.

Sue Nelson
Well, that's incredible because, you know, obviously I'm very late to all this. And autism covers such an enormous range of conditions as well is that the earlier people get diagnosed, the more likely it is to help them particularly with some of the anxiety related issues that adults will get with autism or like you say, communication. So that would be a huge benefit, wouldn't it, to society?

Clare Elwell
And the other thing that was interesting about that study on these four-month-old infants is that there is a behavioural measure that you can perform on infants of that age, which is looking time. So the other way of investigating an infants response to these social human cues and non-social cues, is to see how long they look at the images. And what was interesting in that study is there was no difference in looking time, even in those infants that went on to develop an autism diagnosis at four months of age, the just behavioural looking time signs weren't there, you had to go one step further and actually look directly at the brain responses. And my

colleague, Sarah Lloyd-Fox who is the psychologist who led this work and really pioneered this work in autism, she even then broke down the stimulus. So she was then looking at how babies were separately responding to eye movements, mouth movement and hand movement. And we worked on it together and I was a bit of a cynic saying, “I think you're really pushing the technology here”. But she was really confident. And she was absolutely right. And that's the value, that's the beauty of working with your collaborators, right from the beginning of these projects and understanding and respecting their discipline and, you know, really getting to grips with what the unmet need is, and how we can use engineering to answer questions that are of real value.

Sue Nelson
Well, that was where I was gonna go next, actually, because you know, you've just given several really important examples where the combination of engineering and healthcare and medical physics can make extraordinary contributions.

Clare Elwell
Yeah, and I think, you know, as I'm a medical physicist, as I've said, I've worked in medical physics, my whole career. And actually, the birth of medical physics came from the discovery of X rays, where X rays were, you know, they were these magical rays, no one quite knew what they did, Röntgen discovered them. And he called them X rays, because they were unknown what their capabilities were, and what their effects were. And that first ever X rays, when you look at it, now, it still looks like a really good X ray, actually. And I think that was really the first indication from an imaging perspective that if you understand how the physical principles of interaction with tissue and you understand biology, and you put those two things together, then you can do something extraordinarily powerful. And of course, now we have a whole range of different imaging technologies and a completely different imaging technology, Magnetic Resonance Imaging, relies on really understanding quantum mechanics and nuclear magnetic resonance, you have to understand about tissue contrast, and you have to understand about the biological structures within the tissue that you're looking at.

Sue Nelson
It's this cross discipline again isn't it?

Clare Elwell
Absolutely and that's really what I've loved about that's what's kept me in this discipline is that I'm working with psychologists, clinicians, sports scientists, sometimes plus a range of different engineers, mathematicians, biochemist, physiologist, you know, we're becoming less discipline specific, because we're looking at what problems do we need to solve actually, rather than what discipline do we need to bring to this? It's like what combination of disciplines are going to help us solve this problem? And I think that's something that really excites me about science and engineering.

Sue Nelson
And what sparked your interest in medicine and medical physics and that side of things?

Clare Elwell
So my mum was a nurse and so I rather perversely grew up loving the smell of hospital because it just reminded me of my mum, I spent quite a lot of time in around hospitals. Sometimes when she was working, I would go in there and do my homework in the corner and stuff. And everyone told me I was going to be a doctor, because I always expressed an interest in anything medical, but I was less keen on the biology and chemistry, I have to say, and I was a bit worried about going to medical school because I thought there's lots of biology and chemistry in medical school. And I was very lucky, I was sponsored to go to an event called The London International Youth Science Forum when I was 17. And this is an event that's still going now it's in its 63rd year,

and it brings together about 500 students from 70 Different countries across the world for two weeks for a residential forum in London. And I was just thrown into this environment. And I signed up to anything, there's a range of different topics that you could learn about. And I signed up to anything that had medical in the title. And that brought me to a visit to the Royal Marsden Hospital in London, where I was learning all about a topic I'd never heard of before called Medical Physics. And I stood in front of a medical physicist who explained how an imaging system worked. And in that moment, I knew that that's what I wanted to do.

Sue Nelson
And I love the fact that you are now president of the International Youth Science Forum.

Clare Elwell
Yeah, and only yesterday, I was doing some interviews of students who are presenting their projects so that we could award a prize to one of them to attend this year's forum. And I'm so privileged to be in that situation. It's an amazing event. We have incredible speakers, each year now we have a Nobel Prize speaker at the event. For example, last year, we had Sarah Gilbert was a keynote speaker talking all about the Oxford AstraZeneca vaccine and her work on that. And the students just get exposed to such amazing science. They go to different scientific institutions, during their time in London, go all across the country, visiting all these amazing places. And I can see the impact that it's having on this generation of students is even more powerful than the impact it had on me. Because when I was a student back in 1984, we couldn't keep connected in anything other than writing letters to each other. Now, we're creating this really powerful network of young scientists globally, who we can see are supporting each other during their careers. And, yeah, it's a great privilege. And it's a real joy in my life, that I'm still connected with the forum.

Sue Nelson
That's brilliant. Now, I mentioned the gates funded bright project in the cue, which was supposed to be a five-year project started in 2015. You don't have to be brilliant in maths to realise it gone way over its expected lifetime. Maybe you could explain the project in a little bit more detail and we'll then get on to why it’s still going?

Clare Elwell
So yeah, so we were working, Sarah Lloyd-Fox and I and publishing these data from the infant studies that we were doing and four month olds, separately, I had been approached by a group that were working in India that wanted to see if they could use our technology to look at cerebral malaria. A group in the Gambia read both sets of papers, they read the paper about the use of this technology in India, and they read Sarah's papers about the use of it in infant brain development, put the two together and contacted me and said, “Do you think that we could use your technology to look at infant brain development in Gambia in a very resource poor setting?” And my response when people ask me anything like that is, well, we may be able to do this, but I need to be convinced there's value in us doing this. So what exactly do you think our technology could bring? And their specific question was, “we are concerned and we know that infants who suffer malnutrition in the very early stages of their life, that has an impact on their brain development. We just don't know enough about why, we don't know enough about what types of nutrients are important for brain development. And we don't have any way of measuring what's actually going on in these infants’ brains from birth”. And so that was enough of a really incentive for me to say, “Well, I think we should really try and help with this”. I was then introduced the Bill and Melinda Gates Foundation, we managed to get some pilot funding from them. So we just literally packed up one of our systems flew out to the Gambia drove with a Landrover out to the field station, and were able to set the system up within two hours, and do our first study. And that then turned out to be the first ever brain imaging of infants in Africa.

Sue Nelson
So in terms of what you will do in the future, will it be to expand the project, or to just look at the existing research in more detail?

Clare Elwell
So we want to do both. So, I think we really want to try and package this technology in a way so that we can have it being used by other resource poor research groups working in different areas globally, where there are different types of risk factors for infants. So in the Gambia, it's predominantly malnutrition. But if you go to we've been working with a group in Bangladesh, in Dhaka, infants, they're suffering from very high levels of diarrhoea, because many of them are being brought up near and around slums. So there's a high level of infectious disease. So even if the infant's being given reasonable nutrition, they're not able to absorb that nutrition effectively, because of the levels of diarrhoea. So for every application, we need to understand the context of where we're working. We need to work incredibly closely with the local scientists and field teams there. But ultimately, I guess my role is to make sure that that technology is fit for purpose in all those different settings. So we have challenges like high humidity and lots of dust and sometimes unreliable electricity. Plus, we need to make sure we've got on site training in place. And yeah, so there's been lots and lots of challenges. And for myself, no background in global health, no background in nutrition. It's been, it's been a steep learning curve. But again, hugely exciting to come sort of at the that stage of my career where I don't think I was looking for new challenges, because there were lots of things happening already. But for this to come in at that stage, it is just massively reignited my sort of excitement about the capabilities of this technology. And I think a lot of it is in communication actually. I think a lot of it is in being very open to listen to what other experts in other disciplines have got to contribute.

Sue Nelson
It's interesting you say that, because I read in an interview that you mentioned communication as a key skill, and particularly from a female experience. And you'd actually said, if you're going to be something like, stereotypical, "it's about leaving ego at the door".

Clare Elwell
Yeah.

Sue Nelson
So do you think there's a big difference between, a different sex approach to ego?

Clare Elwell
Yeah, so I've been in plenty of rooms where I've been the only female and often I'm chairing the meeting. And we're talking sometimes 15-20 years ago. And that could be challenging because I could feel that there was a little bit of resistance, shall we say, in that situation. And I think as soon as you can cut through that, and just focus everyone in the room, "why are we here", respect, everyone's contribution, respect, that we're all got many degrees, we've got letters after our name, you know, we've all got that, let's leave that at the door. And let's come in and be open and honest about what we think we can contribute, and what we can learn. And I think that the learning bit is really important. I mean, I'm not an expert in lots of the fields that I've ended up working in. But I was very lucky when I first came into my first role in medical physics on the neonatal intensive care unit, that I was working with doctors all the time, and doctors are just brilliant at, you know, see one do one teach one, I think that that that phrase is a little bit toxic, but actually, they're very good at communicating with, they're very good at teaching on the spot. So I learned very quickly, to keep my ears open and my mouth shut for a period of time to just absorb what was going on around me to understand the context in which I was working to listen, and then to start asking questions. To know that I was an expert in a very small part of what

was going on at that bedside, but the rest of it, I had to really be able to pick up. And I think that if you're not prepared to keep learning, you're probably in the wrong job. And if you feel that you can go into a situation and know everything. That's a pretty dangerous territory, I think to start on. So, yeah, there have been some challenges along the way.

Sue Nelson
Speaking of challenges, I'd also read that you'd worked part-time for 18 years, which actually for somebody in academia, to also still make professor is really unusual. And that can't have been easy, because I read that you've been told you would never make professor, is that true?

Clare Elwell
That is true. Yeah, the day that I got my first fellowship, which happened after my PhD. So a fellowship is a secure amount of funding that allows you to work on a certain project, and it's actually quite prestigious to get a fellowship. And it's a really good thing to have early in your career. The day I found out, I got a fellowship from the Medical Research Council, I found out I was pregnant. So I immediately thought, "Okay, this is going to be interesting". I contacted the funder and said, "Look, this is my situation". And they responded and said, "We've never had anyone in this situation before. Why don't you tell us how you'd like to manage this". And so I said that "I think I'd really like to work part-time". So my fellowship was for three years full time, and I said, "Could I work part-time, three days a week and essentially extend my fellowship to five, five years", and they agreed, and that was really forward thinking of them. Because this was again quite a long time ago. My daughter was born in 1997. So I started working part-time, as soon as I had my first child, and I was then pregnant, actually on maternity leave with my son, my second child, when a lectureship job came up at UCL and my boss called me and said, "look Clare there's this lectureship job" and I said, "I'd love it, but I'm not going full time. I've you know, I can't not with two kids under two, I can't do that". And so he said, we'll just apply anyway, so I just applied and was very transparent again saying that I'm really interested this job but I would only accept it part-time and I got offered the job. So there's a story there about if you don't ask you don't get if you just write yourself off immediately, then you won't, you know, you've got to be in it to get the opportunity. And then when I got my promotion to Senior Lecturer that then dean of the faculty came into my office and said, "Well, congratulations on your promotion to senior lecturer. But you know, you'll never make professor part-time". And I can remember, just as he left the office in this flourish, I remember thinking, "well, actually, that's okay. Because I'm not going to change, I'm not going to compromise what I think is important to me and my life at the moment for that goal", actually, because I hadn't been, I think, because I didn't come from a hugely sort of university, academic based family, I didn't have this massive goal that I have to become a professor, that was something "Oh, wow, that might happen in the future. But I don't know". I didn't sort of dig my heels in and say, "I'll show you" I just thought, well, "I've done pretty well so far part-time. So I'm just going to carry on doing what I do". And so it was a big moment, actually, when I'm a professor and I was still working part-time at that point. Yeah.

Sue Nelson
That's good as well because, you know, you'll often see on social media, particularly younger people who are sort of straining and fighting against academic life and the structures and the long hours. I think knowing that makes it more acceptable, that actually, you can go part-time for whatever reason, because it's not just women, either. It's carers, it's men who I remember meeting, an engineer had taken a lot of time off because his wife had had cancer, and things like that. So there are all sorts of reasons why people want a work life balance. And like you say, sometimes you just have to ask.

Clare Elwell
I always think about when my experience of mentoring other researchers, particularly female researchers, is one of the questions that I ask them early in our discussions is, "what do you think of the barriers out there?"

and then we deconstruct what are real barriers and what are perceived barriers. Because I think there's still a lot of perceived barriers that aren't necessarily there. So things like funding, I mean, I've been able to encourage some of my team if they've wanted to work part-time, and gone to the funders and said, “Look, we'd like to rejig this funding to enable this person to work part-time”, and actually been successful in doing that. So I think some people think, well, I can't go part-time, because what's going to happen to my funding or what's going to happen to my output? I think we're slowly, not quickly enough, we're slowly enabling people to be recognised on their pro rata output. And if you're working part-time, you it should be acknowledged that your output will be adjusted as such. And that relies on promotions panels being informed about that. And when you're in job interviews, it does require a level of transparency. And people are uncomfortable about that. And I certainly have had several instances in my career where I've been told to hide my part-time status, as if it's something to be ashamed of, I had someone say to me, “you can't put on your application that you're working part-time because they won't think you're a serious scientist” and I said, “well, then look at my output, if you don't think I'm serious look at my output or my achievements”. And that I think it's changing. And I'm really pleased to see that change, particularly I'd say in the last few years. And I think it's changing partly because both men and women are working part-time.

Sue Nelson
And I think the pandemic has made a difference.

Clare Elwell
It has made a huge difference, I think flexible working of course, it needs to be managed well. I think there are really serious concerns about the pandemic, actually overloading female academics, because they seem to have just assumed more responsibility. And I think also, we have to be really careful that, you know, we're all striving for equality in the workplace. But let's not load that responsibility on just the female workforce. We need men and women to make this change together. And you see this happen time and time again, we're already in a in a real minority in engineering, particularly, you know, female professors in engineering, I think it's 5%. So if you then load upon those women, the expectation of achievement, which we're all carrying anyway, plus the responsibility of turning this massive shift of equality round, and being the ones that are contributing to all of the mentoring for women in science, and going out and speaking in schools, all things we're happy to do. But you know...

Sue Nelson
It's too much isn’t it?

Clare Elwell
It is, so we need to distribute that responsibility so that it's on everyone's shoulders, and I think I work with lots of men that are more than happy to take that responsibility. It's a big ship to turn, though we have to do it together and we can't load all that responsibility on women.

Sue Nelson
Finally then, is there an invention or development that you think should be nominated for the Queen Elizabeth Prize for Engineering or maybe it could be your first choice, it could be something that perhaps, like permanent magnets, which one this year isn't always as well-known as other inventions or advances.

Clare Elwell
You know, I would nominate a technology that one of my colleagues has developed, which I think is incredibly clever and incredibly exciting. It's called photoacoustic imaging. And it basically is a technology that listens to the sound of light. That's what it does. So you shine light into tissue, and you generate ultrasonic waves, from

the very small explosions that the light creates in the tissue. And then you use those ultrasound waves to develop the most exquisitely detailed images of blood vessels and of tissues and tumours and I think it's a technology that very few people have heard of, but we're really going to be seeing the advances in their technology making real differences in the way in which things like cancer are not just diagnosed, but also when we go into surgery, helping surgeons understand that delineation of tumours, for example, when they're removing tumours to make sure they've got rid of all the tumour tissue, understanding behaviour of blood vessels and oxygenation at that level. I think it's super clever, right. because it combines light and sound together. And it's really classically brilliant physics and engineering. And it's, I think it's a one of the unsung heroes of medical imaging. So photoacoustic imaging that would be my prize.

Sue Nelson
That sounds amazing. So I wouldn't be surprised if someone from there featured on a future edition of the Create the Future podcast but Professor Clare Elwell, for now, thank you so much and thank you for joining me.

Clare Elwell
Thank you. It's been a pleasure.

Sue Nelson
You can find out more about the Queen Elizabeth Prize for Engineering by following @qeprize on Twitter and Instagram, or visit qeprize.org. Thanks for listening and see you again next time.