Dr. Walter Greenleaf:
It's very clear that the more we can add additional sensory modalities to the experience, the more engaged cognitively people are. It doesn't take a lot. In many of the virtual reality demos we do at our lab at Stanford, we have an experience where there's a tall ledge that people are standing on, wearing their head mount display, and fewer than 30% of the people that we show the virtual environment to can take a step off that ledge, even though they know that they're in a room talking to their friends. They feel so engaged that they're really there, that they can't take that step.

LuAnn Heinen:
That's Walter Greenleaf, visiting scholar at the Stanford University Virtual Human Interaction Lab, and Director of Technology Strategy at the National Mental Health Innovation Center located on the University of Colorado's Anschutz Medical Campus. A behavioral scientist and medical product developer, Dr. Greenleaf holds a PhD in neuro and bio-behavioral sciences from Stanford University. He's known internationally as an early pioneer in the medical application of virtual environment technology and as founder of the field of medical virtual reality.

I'm LuAnn Heinen, and this is the Business Group on Health podcast, conversations with experts on the most important health and well-being issues facing employers. My guest is Walter Greenleaf. We'll discuss how virtual reality and augmented reality environments are used to treat mental health conditions like addiction, phobias, and PTSD today, and take a look at what the next decade may bring.

Today's episode is sponsored by Pear Therapeutics. Pear Therapeutics discovers, develops, and delivers clinically validated software-based therapeutics to provide better outcomes for patients, smarter engagement and tracking tools for clinicians, and cost-effective solutions for payers.

I'm looking forward to today. We're going discuss why we may now be at an inflection point for the adoption of virtual or extended reality, immersive technologies, and digital therapeutics. As part of that conversation, we'll hear about some novel applications in health care related to mental health, behavior change, better aging, and chronic pain management. We'll also look into the future where wearable sensors, our connected devices, and the cars we drive, could all offer a window into our physical and mental state. But let's back up, welcome our guest Dr. Walter Greenleaf, and start with an overview of the technologies we'll be covering and the terminology that goes with them. Walter, welcome to the podcast.

Dr. Walter Greenleaf:
Thank you. It's wonderful to be with you today.

LuAnn Heinen:
Tell me a little bit about this terminology. What do we need to know? VR AR XR? What should we be thinking about?

Dr. Walter Greenleaf:
Well, I think the main thing to know is that the technology is evolving and changing. We have gone from the terms virtual reality and augmented reality technology, now we tend to say VR and AR. There's an evolution of our comfort level and familiarity with the terms. At one point, VR as a term sounded very glib and informal and sort of science fiction, but now it's becoming to have some very specific connotations. But there are other terms that are emerging hand in hand with AR and VR, and that is mixed reality, immersive technology, extended reality, medical extended reality. We're still seeing an evolution of the terms, but what I tend to say is either VR as a catch-all phrase for all the different forms of interactive three-dimensional simulation technologies, or I tend to say immersive technology, immersive systems. But I think we still have a lot of evolution of the phraseology to occur.

LuAnn Heinen:
Thank you so much for that clarification. That's helpful. Stick with VR and immersive technologies. Why is this kind of technology so powerful and advantageous in health care?

Dr. Walter Greenleaf:
There's several reasons. One is that virtual environments, immersive environments, are very good at promoting adherence because they can be very cognitively engaging and because we can put a layer of narrative storytelling on part of the experience. The technology has become adherence facilitators. We've had a lot of problems with digital health applications in terms of people sticking with them, but due to the very engaging nature of immersive technologies, we now have some new tools to promote adherence, which is very important to have effects, especially anything involving a chronic medical condition. The other reason these technologies are, I think, going to make a profound difference as we move forward in health care, in particular, mental health care, but not exclusively, is because they provide a new way of evoking and recording a cognitive response to a challenge or a physical response to a challenge instead of having subjective measurements of someone's mood or their cognitive status, because we can challenge our behavior, challenge our cognitive processes with a very compelling, immersive experience. We now have new ways of being more objective in our measurements of mood, of affect, of cognitive processing, and also in physical medicine, because in a virtual environment, we can capture movement very precisely. We have new tools now for traumatic brain injury rehabilitation or stroke rehabilitation, because we can more objectively measure functional movement.

LuAnn Heinen:
Because the clinician can measure functional movement and improvements, let's say in rehabilitative medicine, what's the patient experience like with VR?

Dr. Walter Greenleaf:
Well, two really powerful and amazing improvements are brought in by the use of virtual environments. One is because we can make the experience less boring, less repetitive, less like doing exercise, you don't have to have the personality of an athlete to go through the rehabilitation process. We can make it more of a game-like experience or a participatory experience with other people. We can also give direct feedback of progress, which makes a big difference. If you have a long journey to go on, but you can't see where you are on that journey, it can often be discouraging not to feel like you're getting any place. The other power is that we can refine protocols in a more precise manner. Being able to measure an individual's response, see where they are in terms of their progress versus their treatment goals and treatment protocols, and adjust dynamically the protocols based on more precise measurements, makes a big difference. We now can apply precision medicine techniques to both mental health care and physical medicine.

LuAnn Heinen:
I've heard you talk about VR can leverage the brain's reward systems. What's an example of that?

Dr. Walter Greenleaf:
One example might be, if we're trying to help someone deal with a phobia or post-traumatic stress or addressing anything that's uncomfortable or if we want to help people stay on the course of therapy, we can make their experience more of an engaging experience because with VR technologies, we can place you someplace else, have you feel like you're with other people in an engaging environment and we can make it fun, we can make it exciting. It can be a challenge or it can be something where you rehab, but it's with other people who also have the same challenge that they're going through. You can see your progress. We can gamify, to use that phrase, the whole experience. And that just allows us to bring a whole layer of enhanced motivation. We can take some of the techniques that our friends and colleagues in the film industry and in the game industry have used to bring people back to their games and to keep watching their television series. We can take those techniques and now apply them to some difficult medical processes.

LuAnn Heinen:
I like that you've also mentioned that it's powerful because all the senses are involved. The body takes in more, faster information quickly. It seems like the brain is firing on all cylinders and then even incorporating new senses, like smell.

Dr. Walter Greenleaf:
One thing that's very exciting is that we know that we can enhance the feeling of presence in these virtual environments by adding more and more robust engagement using our senses. So, it's not just the visual experience that one has in a virtual environment. We also have spatial audio. We capture movements of the body, your hands and your arms, and in some cases, your legs and the rest of your body. You can move around in the virtual environments, pick up objects, do things with them. There's some new technology by a company named OVR that brings a sense of smell to virtual environments in a very robust manner. It's very clear that the more we can add additional sensory modalities to the experience, the more engaged cognitively people are. It doesn't take a lot. In many of the virtual reality demos we do at our lab at Stanford, we have an experience where there's a tall ledge that people are standing on wearing their head mount display, and fewer than 30% of the people that we show the virtual environment to can take a step off that ledge. Even though they know that they're in a room talking to their friends, they feel so engaged that they're really there, they can't take that step. The more sensory modalities we add to virtual environments, the more compelling they become and the more we can use them to facilitate engagement, participation, adherence.

LuAnn Heinen:
I would be in that 70%. In fact, I've tried it at a little field trip to Meta and could not step off, could not.

Dr. Walter Greenleaf:
It's amazing how robust the environments have become and how we really do feel like we're someplace else.

LuAnn Heinen:
One of the things that blew me away was in the *New York Times* recently, just in April, the statement that VR treatments may provide relief similar to intravenous opioids, which is something that is being looked at for the 50 million Americans who are living with chronic pain. This reminds me of something else you've said about how VR can change your brain. So it can change your brain potential in a way that you're not feeling pain. Can you talk a little bit about how that works?

Dr. Walter Greenleaf:
Absolutely. A good phrase that my colleague Jeremy Bailenson uses to describe VR is that it is experience on demand. And because we can create an experience for people that is so compelling, we can distract them from uncomfortable experiences. We can put them someplace else, distract them from the uncomfortable or the painful experience. This allows us during an acute painful process to really grab their attention and take it away from what's going on. For chronic pain, we can use that VR as a platform to teach them stress mitigation skills, mindfulness skills, and other cognitive behavioral therapy approaches that help address the chronic pain. Consistently we see time and time again, and validated in many different ways, that this does allow us a way to produce the use of narcotics to address pain.

LuAnn Heinen:
But does it go beyond distraction, because this article seemed to suggest that sometimes your brain gets stuck in a pain mode and it's feeling pain that may not actually be pain. Your brain could be changed so as to not perceive or feel the pain.

Dr. Walter Greenleaf:
You're absolutely correct. A major part of the experience of chronic pain is a learned fear response, that the experience that the individual may have exceeds the actual somatic experience of pain. What we can use with a virtual environment is we can teach people through different cognitive behavioral therapy techniques, ways to address that and mitigate the experience of pain. We've also seen where people often will have a limitation to the range of motion because of their pain experience by giving them feedback and distracting them from the acute pain that they may be having. We can teach them if they really do have a larger range of motion that they can do without pain. It's really a matter of feedback. It's a matter of giving them information about how to manage their pain and to reduce that learned fear response by teaching them through cognitive behavioral therapy some techniques to manage their pain.

LuAnn Heinen:
That's really fascinating and wonderful. You've worked in this space now for something like 30 years. Why so many years of research and development now seem to be really bearing fruit in health care? What about this moment?

Dr. Walter Greenleaf:
Well, we've had virtual environments for research purposes for decades. There's been a number of really very talented scientists putting their attention to how can we use simulations, virtual environments, as part of both education training and clinical care and improved assessments. The reason things are moving out of the research lab into clinical care right now is that previously, even though we had an understanding of invalidated approaches where virtual environments could be helpful in clinical care, the technology was uncomfortable, it was expensive, and it was just difficult to get access to. Now, you can get a really robust virtual reality platform for less than a third of the cost of a smartphone. It makes it an affordable platform for health care delivery and also a platform to help people learn wellness and preventative medicine skills. I think we're getting a lot better at having the right sort of content that is engaging. We're getting better at having the right development platforms for virtual environments, more than just improvements to the technology. There's been a real shift in our culture about acceptance of technology as a layer in medicine. The digital health revolution has been going on now. It's been enhanced by needs to respond with telemedicine to the pandemic crisis. But in general, now we feel more comfortable of having a layer of technology as part of our health care. As a matter of fact, in some cases, patients are surprised and disappointed if we're not leveraging technology. I think the other important thing to keep in mind is in addition to the shift in our attitudes about health care and ways of delivering health care, there's been changes in the regulatory environment to support some of the confluent technologies that support virtual environments in health care. By that I mean, 5G, machine learning and analytics, improved graphical rendering systems, new ways to take data and apply it in a precision medicine approach. VR and AR technologies are fantastic ways of enhancing adherence and getting more objective measurements, but they're evolving hand in hand and I think have come over a threshold, along with the other technologies that are supporting the evolution of digital health technology.

LuAnn Heinen:
Let's talk about an example of increasing adherence either from research or practice.

Dr. Walter Greenleaf:
Well, one example might be how we're now able to help people who have to go through the often arduous process of recovering from a stroke or traumatic brain injury. We have fantastic systems that will allow them to have tasks that might start out very easy, get more and more difficult as the patient progresses and using the measurement of their function as a way to dynamically change that progress. But what the user sees is they might be in a large pinball machine playing pinball with the movement of their arms, or they might be going to a very beautiful location and using that as the venue for them to do their exercises that they need to do to recover function. Or we might have a multi-user environment where they're with a clinician and perhaps a few other people with a similar injury and going through the rehab process and they're playing a game with each other.

LuAnn Heinen:
So your PT exercises that you really don't want to do, become much more fun when you put on a headset and maybe join others.

Dr. Walter Greenleaf:
Probably more importantly is we can give you feedback about your progress and that's often one of the most important things. It's a long road sometimes to full recovery, but we now know that we can take people who have plateaued in their recovery, sometimes they've been at one point for up to 10 years, we can bring them back, put them in a virtual environment for rehabilitation and with the proper protocols and motivation, improve their function even 10 years after the stroke or injury that they had.

LuAnn Heinen:
Well, let's talk about a mental health application.

Dr. Walter Greenleaf:
Well, we've had some fantastic ways of addressing some otherwise very difficult problems using virtual environments. We talked about pain, but we can also look at anxiety, depression, helping people with attention deficit disorder, people on the autism spectrum, people who are dealing with post-traumatic stress. The techniques we use in mental health care are similar to what we've talked about for addressing problems with rehabilitation. We can teach people the cognitive skills they need to manage a situation and help them address, perhaps, their learned fear response, if we're addressing anxiety. To give us a specific example with post-traumatic stress and with phobias, we use the technique of exposure therapy, where we gradually expose people using a virtual environment in a controlled way to things that might be triggering a panic attack or a big problem. We can teach them the management skills to address those things that are triggering the learned fear response.

For someone who's had a traumatic experience, it's very hard to ask them to use their imagination to review that experience. Their brain just doesn't want to go there, but it's important in order to process that experience and to learn the skills to manage it, that you do consider it and you do review it. A clinician can use the virtual environments as a platform for discussion to take them back to the experience that caused the trauma and help them assess it cognitively and learn the skills to manage it and to relax, perhaps, when they're exposed to the thing that is triggering a fear reaction to them.

LuAnn Heinen:
I'm talking with Walter Greenleaf of Stanford's Virtual Human Interaction Lab. We'll be back in a moment.

Pear Therapeutics
Prescription digital therapeutics, or PDTs, are software-based medicines to treat serious disease. At Pear Therapeutics, our mission is clear: we are pioneers in PDTs. Our cross-functional team operates at the intersection of biology and software technology, where researchers and clinicians work side by side with software engineers and developers to create the next generation of therapeutics. Pear discovers, develops, and delivers clinically validated software to provide better outcomes for patients, smarter engagement and tracking tools for clinicians, and cost-effective solutions for payers. Every day, we push the boundaries of technology to transform medicine.

LuAnn Heinen:
I'd like to ask you what areas of medicine is VR and AR technology moving into most rapidly?

Dr. Walter Greenleaf:
Well, it's been exciting and interesting for me to see that there's been a pretty rapid adoption of using VR and AR technology into the emerging area of medicine, of psychedelic supported therapies. As you know, there's been some real excitement and a lot of investment, a lot of momentum, at developing new applications of ketamine and psilocybin and other psychedelics, to help address anxiety, depression, addictions, some very often difficult problems in mental health to address. What's been interesting for me is to see that there's been pretty rapid adoption of applying VR and AR technology as part of that therapeutic process. Now, to be clear, it's not so much people wearing a head mount display while they're taking psilocybin in a clinical context, it's more using the virtual environments in two very important ways. One is to prepare the patient for the psychedelic supported therapy process by setting the right set and setting.

We can use virtual environments to reduce anxiety, which often people might have before having a new experience such as taking a psychedelic, and to prepare them for what that experience might be like, teach them stress mitigation and relaxation techniques in advance, and there's a compliment to the therapy. Also, after the experience, there's a need to sort of debrief to do what they call the post-session integration. Many of the companies that are developing this next generation of therapy also have a challenge of educating the clinicians. It's a new technique. It's a new approach. It's something where we need the right therapeutic

approach and we can use simulations as an educational context, teach the clinicians how to handle an adverse event. If somebody has a bad experience, how do you help them? If they're angry, if they're anxious, if they're depressed. Both as a way of preparing the clinicians to do the therapy and training them, and then also preparing the patients. Virtual environments have tremendous potential.

LuAnn Heinen:
That's so interesting. Can we talk about the use of avatars? When is the patient being treated represented by an avatar or when is someone just in a beautiful virtual environment?

Dr. Walter Greenleaf:
Well, one of the amazing capacities we have when we use virtual environments is that we can allow the user, the patient, to see the experience from a variety of different points of view. They can have sort of a first-person point of view or they can look at perhaps a prerecorded session from a third-person point of view and see themselves in their behavior. What we might see with an avatar is how it's good for role playing. A clinician can join a patient in virtual environment. The clinician can take on an avatar of a different gender, a different ethnic background, a different age, and also so can the patient. We can make a representation of their future self and they can see how cutting back on their use of alcohol or having better nutrition or adhering to wound care better will affect the health and happiness of their future self.

LuAnn Heinen:
Let's talk about how that happens. How is our future self-created in VR? Let's just say our future older self, if we've been smoking and drinking and not eating well, how does that happen and how is that believable?

Dr. Walter Greenleaf:
We can have some very robust avatars now that look and move like a human body moves and we can overlay those avatar models with an image of yourself. We can take a picture using a camera on your phone or a webcam and then put it onto the skeleton of your avatar. You can also, if it makes sense, customize that avatar, changing its weight, changing its height, etc. For giving feedback about your future self, what we do is we age progress the avatar. There's a process of bonding with your avatar, I guess to use that phrase, where we have you be in a virtual environment and you see yourself in a mirror, you wave your hand, your future self waves his or her hand. Then you can look at yourself from a third-person point of view, also, see the choices you make and the responses.

It's a powerful way to connect you. We've got the algorithms to do the age progression, all the other things right now. What we're working on right now is what's the best protocol to utilize this technique as a way to help people shift their behavior and their attitudes. By the way, we also use this approach when it comes to helping people address perhaps to D&I training and help people understand their own biases. You can have an experience of what it's like to be in the body of someone with a different ethnic background or gender, see what it's like to have the challenges that our culture might present. It's, again, a way to have an experience that can allow you to see what it's like from a completely different point of view and that can be a very powerful way to facilitate change in behavior.

LuAnn Heinen:
Has that been used, for example, quitting tobacco, you mentioned reducing alcohol use?

Dr. Walter Greenleaf:
Yes, it has. There hasn't been a lot of use of the future self-approach outside of the research environment, but there are some groups that are starting to move that over. But we do use that third-person point of view of your avatar or the first-person experience using an avatar to allow people to have an experience and reduce the anticipatory anxiety of a social encounter, for example. Someone who's dealing with social anxiety disorder, we can have them practice what it's like to go to a party and make friends and introduce yourself, or for someone who has perhaps been sheltering in place during the pandemic and is now starting to return to the work environment and maybe has some anxiety about that, we can have them rehearse going back to work and talking with their friends in the cafeteria in advance to help reduce the anticipatory anxiety.

LuAnn Heinen:
Another thing that I know that is on the horizon is the use of VR and immersive technologies to improve brain performance in older people, but also, as you mentioned, in people who've had brain injuries and not necessarily just older people, although you've talked about the chain, the cognitive decline, or the less ability to multitask that takes place from the time we're in our twenties. What do you see coming in the area of brain performance as potentially the next fitness frontier?

Dr. Walter Greenleaf:
It's a very interesting question, because it does get to sort of the heart of the matter of what are the edges of what we can do with VR and AR technology and how is it relevant to some of the major health care problems that we have? One of the looming health care problems, of course, is with an aging population. What we see with aging is increased propensity for people to have neurodegenerative diseases such as Alzheimer's or Parkinson's. What we can do to help mitigate those problems and also help with palliative care for those problems if they do develop, is use VR as a way to promote better preventative health measures, such as better sleep, better nutrition, etc. Then when somebody does develop a problem such as Parkinson's or Alzheimer's, we now have new techniques to both measure, evaluate how they're doing, and perhaps provide interventions that might support their care.

I'm excited about the work of Adam Gazzaley's group. You referred to this when you mentioned ability to reverse some of the cognitive declines we see with aging. Adam's group has been able to use virtual environments as a way to address some of the executive function declines that we see as people age, starting in our twenties. Every year we slow down in some aspects of our cognitive function, but Adam's group is able to show that by using immersive virtual environments that they can reverse some aspects of that cognitive decline. Extending from that, I think we can come up with just like going to the gym helps mitigate and address some of the physical declines that we get with aging, such as sarcopenia. We can also leverage virtual environments as a way to boost brain health and hopefully prevent some of the neurodegenerative diseases and common decline that we see with that.

LuAnn Heinen:
Let's talk for a minute about VR and digital therapeutics. What are digital therapeutics and why is VR the latest trend in this space?

Dr. Walter Greenleaf:
Well, the term digital therapeutics refers to when we use technology such as cell phones, mobile phones, computer technology, to provide a therapeutic intervention and to monitor progress. Right now almost every medical device has been moved from an analog to a digital format. We're coming up with better ways of leveraging the information we can get from those devices and building them into engaging therapeutic platforms. There's a whole spectrum of them. The role that virtual reality plays is, I think, promoting better adherence. What we do find with many digital therapeutics is after a while they become a little bit less interesting and people drop off and don't continue to go back to them, especially those in the mental health arena where the adherence rate is very low. But with virtual environments, we find that people have a much higher percentage of staying with it.

We also see when we use virtual environments as part of education, there's a higher retention. First year medical students who are learning anatomy when they had to shift over to using virtual cadavers in a virtual environment to learn during the pandemic, we were able to see tremendous amounts of increased retention by using that platform. To get back to your question about examples of where VR can make a big difference as a digital therapeutic, I think it starts with much better assessments using virtual environment as a platform. Again, we can take things that are often very subjective, such as when we ask someone how do you feel today or how did you feel last week or how did the use of that medication affect you? It's very hard to honestly describe or accurately describe their subjective experience. And it's hard as a clinician or a research scientist or a product developer to build and develop and validate products based on subjective reports.

But with virtual environments, we can use them as a platform to both evoke a cognitive response or mood response or behavior, and then objectively measure those behaviors. That will allow us to come up with a new generation of digital therapeutics that start with a more precision-medicine approach of matching protocol to the individual, and then better ways of dynamically measuring progress. I think we'll also see, because of the ability to bridge space and time with virtual environments, we'll start seeing them being used as part of post-discharge follow up, a way for people to stay connected with their clinicians in a perhaps asynchronous manner by having a recording of the clinician's avatar that can provide information in response of a question much better than handing someone a stack of Xerox sheets of paper when they're discharged. There's a variety of ways we can just enhance communication and enhance feedback to the patient.

LuAnn Heinen:
Which of these are commercially available now, FDA approved, on the market?

Dr. Walter Greenleaf:
There have been a variety of different VR and AR applications approved by the FDA for therapeutic care and also a number of them have been applied to presurgical planning, for example, or overlaying the surgical operating field with extra information to guide a neurosurgeon, for example, as they're removing a tumor. So there's been a spectrum of approved VR applications, starting at evaluation, moving into clinical care, and then supporting post-discharge.

LuAnn Heinen:
What do you think employers should know now and what should they be keeping an eye on, thinking about the working population and their families?

Dr. Walter Greenleaf:
Well, employers should be excited about the way this emerging technology, as it gets further out, will make a big difference in terms of improving rates of return to work, post injury. I think employers also should be aware that VR is a fantastic way to help promote health and wellness. It's a way to facilitate a healthier workforce by introducing VR technologies. There's a number of programs that have been designed to facilitate and improve health and wellness by using VR relaxation and stress mitigation skills. Then again, we've had great success with using VR to help address problems with nicotine and with alcohol and other addictions.

LuAnn Heinen:
Going back to the health and wellness relaxation application, so instead of just a cell phone application for meditation or relaxation, you're saying to add the headset, those are sold separately by different companies, those kinds of modules, because I don't think they're commonly available in the workforce well-being space.

Dr. Walter Greenleaf:
Well, we're starting to see a number of virtual reality applications designed to reduce stress and facilitate health wellness being provided to employee assistance programs. They often take the form of, instead of having teaching someone a guided meditation technique, for example, to promote mindfulness, they instead may bring them to a virtual environment that is very cognitively engaging, where they need to just focus their attention and that will take them away from some of their worries and anxieties. Other virtual environments are used to teach specific mindfulness skills. They're not out there, as well as they will be in the future. I think we're just getting started at moving them into this zone. Part of the problem has been that not everyone has a head mount display at home. We have some powerful applications that can be used for both clinical care and also to promote health wellness. I think it was Alan Kay who said the future is already here, it's just unevenly distributed. I think that's very much the case with some of these techniques and virtual reality is we have some validated interventions that can make a big difference, but we're still in the process of moving them out from the academic arena into the clinical arena and the health and wellness arena.

LuAnn Heinen:
When do you think every household will have one or more virtual reality head mounts?

Dr. Walter Greenleaf:
It's a good question. I think that what really will drive adoption is not so much the fully immersive virtual reality environments, but we're starting to see a new generation of augmented reality environments that have a spectrum of immersion, meaning there's a spectrum of how much of the outside world is blocked out. These will be lightweight, relatively low-cost and sort of like a personal head mounted display that will do many things. I think we're all looking forward to when Apple brings its technology out. I think we're going to start seeing a pretty rapid ramp up of both how we use VR for our personal interactions, our personal health and wellness, but also facilitating things like repair of an automobile or learning to recognize the emotional state of others. There will be so many applications and things that we can do, or way finding in a city. I think it's worth noting also that a number of large health care payer networks have been looking at possibilities of providing head mount displays to each of their members as a platform to help reduce health care costs and deliver through a telemedicine manner health care delivery. The ubiquity of this technology could happen because of just more and more uses on the consumer level, but we also might say comes from deeper adoption within the vertical of medicine. I'm not sure which will be first.

LuAnn Heinen:
You've said that technology will study us and adapt itself. Now, if we look ahead 15 to 20 years, paint that picture a little bit where data's coming from smart cars, video surveillance, public zooms, cell phone locations. What's sort of the next phase of all of this?

Dr. Walter Greenleaf:
Well, it is pretty interesting if we look ahead. There's things that I think will be quite amazing that are in the process of being developed and rolled out now. There's a lot of work being done by the Tech Titans and also by other groups, leveraging sensors and webcams and other methods to do effective computing. In other words, measuring our cognitive state and our mood affect - are we paying attention, are we sleepy, are we alert, are we in a good mood? As the sensors become more ubiquitous around us, as our technology starts studying us in order to be more effective as enabling technology, we'll see more personalization. That means that our smart cars, our buildings, our computers, or whatever we're using in 10 or 15 years as a platform for communication and work, will be studying us and changing their behavior based on our state.

There's plenty of reasons to feel perhaps a little bit queasy about technology that is adapting itself and studying us in order to be more effective, because there's always the concern that this information could be used inappropriately, but I think it's on its way no matter what, that with the evolution of better machine learning, better sensor technology, ways to look at and evaluate someone's mood state passively just by how fast they type or how fast they're walking, what their gate stride is, I think we will start having really robust ways of leveraging the information to improve health care and also improve the functionality of technology. I think the challenge though, right now, is that we need to make sure that we protect this information very robustly. I think we also need to make sure that we don't build into our data sets biases that we are assertive and aggressive about making sure we build into the data sets that will enable this next generation of medical technology and consumer-facing technology that doesn't have built in biases by excluding certain age groups or patient populations or diverse populations. It's evolving pretty fast. It will be here and I think now's the time to start shaping the direction.

LuAnn Heinen:
Really exciting and a little bit scary, but more exciting than scary, I think. Well, thank you so much for that, Walter. I'm really excited to finally have a chance to bring this conversation to fruition and thank you for your time.

Dr. Walter Greenleaf:
Thank you for the good questions. I very much enjoyed talking with you.

LuAnn Heinen:
I've been speaking with Dr. Walter Greenleaf about immersive technologies. For more on this subject, visit the International Virtual Reality Health Association at https://ivrha.org/. To learn more about Dr. Greenleaf's work,

particularly virtual reality and digital therapeutics, visit the Virtual Human Interaction Lab at https://stanfordvr.com/, see https://greenleafmed.com/ or connect on LinkedIn.

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