Kessler Foundation Podcast Transcript: Guang Yue on Rehabilitation Engineering

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ANNOUNCER: 00:06	[music] Welcome to this Kessler Foundation podcast. The Foundation is a global leader in rehabilitation research that seeks to improve cognition, mobility, and long-term outcomes including employment for people with neurological disabilities caused by diseases and injuries of the brain and spinal cord. In this episode, we're talking with Dr. Guang Yue. He is the director of mobility and rehabilitation engineering research at Kessler Foundation. He spoke with Rob Gerth, the foundation's communications director.
ROB GERTH: 00:39	So you received your undergrad from Beijing Normal University, and that's what it was called. It's not called that now, right? It's called something else?
GUANG YUE: 00:47	Yeah. Sometimes people call it Teachers University--
GERTH: 00:51	Teachers. I saw that. Yeah.
YUE: 00:51	Or Normal University. So yeah.
GERTH: 00:54	And so what was it like growing up in China? What was grade school like? What was high school like? What was getting into college like? Tell us a little bit about that.
YUE: 01:01	Every level of school was very competitive. Elementary school and middle school and high school, you don't have to a pass national exam. Only in college, you need to do the national exam. But even elementary school and middle school, high school, if you want to be in a good school, you have to be very competitive. Your exam score has to be high to be admitted to that school. So my elementary school and middle school and high school were among the best in that province, which was Hunan Province. It's similar like a state. Yeah, China has like 30 provinces. And so the schools I attended were among the best in the province, so it's competitive.
GERTH: 02:20	Yeah, and do you have to test to get into the best school or is that just a matter of--?
YUE: 02:26	Yeah, it's not like here. If you live in this city, you go to school in this city unless you go to a private school. But in China, there is only-- especially at old times, there was only limited resources, so they put more resources on some schools, so the school is much better than other schools which had less resources. So everybody had to compete to get a better school if you really want to, so.
GERTH: 03:01	And was it like a boarding school or was it like a neighborhood school then for you?
YUE: 03:05	It's more like a neighborhood school for elementary school. But for middle school and high school, it's a bigger area. For example, my classmates, some came from more than 100 miles. So we were all actually-- it's a boarding school. We all lived in a dorm in the school, even in middle and high school. So for me, the school and the high school actually it's for a bigger area.
GERTH: 03:42	And at what point do you have to decide what you want to be when growing up in China? Is it early on that you have to decide what direction you want to go or?

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YUE: 03:50	Well, as a kid, so everybody has something they want to do when they grow up. So when I was young, I think a scientist was my first choice.
GERTH: 04:06	Really?
YUE: 04:07	Yeah. Yeah, [laughter].
GERTH: 04:08	Isn't that funny?
YUE: 04:09	Yeah, it's really funny.
GERTH: 04:10	Did you have scientists in your family or--?
YUE: 04:12	No.
GERTH: 04:13	What led you there?
YUE: 04:14	Actually, no, but my father's work was related to science and technology, engineering. He was at the ministry in a government organization focused on hydraulic power. You make dams and put generators and generate power to make electricity to power different things. So yeah, his work was related. But himself, he was not an engineer. He was not a scientist. But he worked with many engineers and scientists actually in that area.
GERTH: 05:04	So early on you knew you wanted to be a scientist. What science did you want to go into? Did you know?
YUE: 05:08	I didn't know [laughter]. I probably dreamed more to be a scientist related to maybe space or physics, something, but I less thought about I become a biological scientist or physiologist or neuroscientist, so.
GERTH: 05:34	All the things that you now are.
YUE: 05:35	Yeah.
GERTH: 05:36	So we'll get to that. I want to find out. I'm going to ask you that question. Hopefully, I'll remember to ask you that question when the time comes, is how you ended up in the sciences that you're in. But before we do that, how did you make the-- so you went to college undergrad in China. How did you make the leap to the US then?
YUE: 05:54	Well, for a graduate program. At that time, I came to the US in 1984. At that time, the graduate programs in China were very limited. Not many graduate programs, especially related to the motor control or something, so very little. But the US had many of those kinds of programs. So, many universities offered opportunities for people to apply, so.
GERTH: 06:34	And you ended up at the University of Iowa for your PhD. How did you end up in the Midwest then of all places? Were you a country boy or a city boy in China?
YUE: 06:44	I was born in the country and then I grew up until second grade with my grandparents on my mother's side as I was in the countryside.
GERTH: 07:03	In the countryside--?

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YUE: 07:04	Yeah. When I reached to second grade, so I moved to my parents' house which is in the city, but not a big city. Maybe a city around 100,000 people at that time.
GERTH: 07:19	Right. So not too big. So you ended up at the University of Iowa. So how did you pick that? Was it--?
YUE: 07:26	Well, there are two reasons. So the first reason, at that time, I started to study English. I wanted to improve especially my conversation in English. So because I was in Beijing, so there were many tourists from the US, from Europe. So one day, I was in a park. It's a famous park and a lot of tourists go to that park. So I started to have a conversation with a person from the US, and actually, he was a professor at the University of Iowa [laughter].
GERTH: 08:10	What luck [laughter].
YUE: 08:11	Yeah. So he asked me about what I want to do. I said, "I want to go to a graduate program in the US." He said, "How about you apply our university [laughter]?" So that was the first reason I ended up in Iowa. And then the University of Iowa gave me studentship. So that covers my tuition and also living cost, so.
GERTH: 08:43	And how was your English at that point where you decided to go to the University of Iowa?
YUE: 08:47	Well, I think my written English was not too bad. I got a pretty high TOEFL score. And my GIE score was also reasonable. But my conversational English was a little bit poor, [laughter]. So it's always my goal to improve.
GERTH: 09:10	Yeah. Well, way better than any of my languages I speak other than English, which is zero, so.
YUE: 09:15	This is a difficult area because when you start to learn another language when you are already an adult, it's really difficult. I can see how my son who, English, he picked up so quickly when he was here, he was only four. Yeah, only about a couple of weeks, he starts talking English and [laughter]--
GERTH: 09:41	That's great. So at the University of Iowa, you ended up studying sensorimotor neuroscience. So tell me how you got into that then.
YUE: 09:52	It's more like motor control. It's motor control, but the program is called sensorimotor neuroscience, so. And also, it's related to exercise science.
GERTH: 10:02	Exercise science?
YUE: 10:03	Yeah. Exercise science. The department is called Exercise Science. But the department has many different PhD programs. There's biomechanics. There was motor control, sensorimotor neuroscience. There was exercise physiology, which is more related to metabolism and those things. And there was also programs related to sports or athletic training and administration.
GERTH: 10:41	Yeah. So what got you there? What clicked in your head that you said, "Yeah, that's the major I want to--" or, "That's the PhD I want to pursue"?

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YUE: 10:47	Yeah, when I was a college student, I was track team. So I always utilized-- I was always interested in motor control, how the nervous system controls our movement. So when I went to the University of Iowa, it was so fantastic. There was a motor control program and I can study towards my PhD degree there, so.
GERTH: 11:20	And I've got to ask, so in track, what event were you? Were you a runner or-- in track, were you a runner or were you--?
YUE: 11:26	Yes, a runner. So a middle-distance runner. My major event is 1,500 meters.
GERTH: 11:34	Yeah, [laughter]. How is your time these days?
YUE: 11:38	Well, it's about three minutes.
GERTH: 11:43	Yeah?
YUE: 11:43	It's not too bad. It's not too good--
GERTH: 11:44	That's pretty good [laughter]. That's pretty good. At a certain age, you've got to be like, "Yeah, that's pretty good."
YUE: 11:51	Yeah, that was pretty good at that time. Now I cannot do that anymore [laughter].
GERTH: 11:54	No [laughter]. So, and then from there, you went on to the University of Arizona. What did you study there?
YUE: 12:06	Yeah. Arizona was a postdoc program. So I specifically contacted my mentor, Roger Enoka. He is a very well-known motor control sensorimotor neuroscientist.
GERTH: 12:27	In China?
YUE: 12:29	No, here at the University of Arizona at that time. So I contacted him, asked him whether he had any opening for postdoc training. And at that time, he'd just got an NIH grant and he was looking for a new postdoc. So that's really good timing.
GERTH: 12:51	Yeah. That was good timing, exactly. So what did you study there? Tell me about the--
YUE: 12:56	When I arrived at Arizona, Dr. Enoka gave me a very specific project to do which is related to the control of motor units. I don't know if you know motor units. A motor unit is the smallest unit in the muscle that can control the force output. You can control, I mean. The smallest, of course, each muscle fiber that contracts, that generates force, but you cannot control each muscle fiber. The only thing you can control is the motor unit. Motor unit is a group of muscle fibers innervated by motor neurons in the spinal cord.
GERTH: 13:47	By what? What--?
YUE: 13:48	By a motor neuron.
GERTH: 13:49	Motor neuron. Okay, in the spinal cord.
YUE: 13:50	In the spinal cord. So the neurons project to a number of muscle fibers and then the axon from the neuron and cell body runs through the muscle and this particular axon of no fiber splits to each fiber. So, for example, a big muscle like quadriceps, each

	neuron controls hundreds of muscle fibers to complete a motor unit, okay? But some other muscles like hand muscle, muscle control eye, one motor neuron only controls like 10, 20 muscle fibers.
GERTH: 14:36	So you were studying each one of those individual groups?
YUE: 14:39	Each of the motor units. Yeah. So the way to study is to put intramuscular electrodes, to insert the electrode by a needle into the muscle. And you observe how when you ask a person to, for example, index finger abduction like this movement, so you ask a person to put against a force transducer. So the person starts to generate some force.
GERTH: 15:11	So I just want to describe for people. So you have a hand flat on the table and between your thumb and your forefinger, you're moving your forefinger towards your thumb.
YUE: 15:17	Yeah, so your thumb will be fixed, so you cannot move your thumb. And these two fingers are fixed. So the only finger you can move is this one.
GERTH: 15:25	Your pointer finger, right.
YUE: 15:26	Yeah. And then so the fingers are against a force sensor.
GERTH: 15:32	Something that's measuring how hard it can push.
YUE: 15:34	Right.
GERTH: 15:34	Got it.
YUE: 15:35	And then since you have the electrode in the muscle, so you start to contract--
GERTH: 15:40	It's actually like a little needle, right?
YUE: 15:42	Right.
GERTH: 15:42	It's like a little needle in your muscle. All right. Okay.
YUE: 15:44	So then you can watch how the muscle fires-- a particular motor unit fires based on the level of muscle, the level of force the muscle generates. So that's what I-- so the specific question he wanted me to look at is, when the person keeps doing this, gets really fatigued, how that motor unit behavior changes, so.
GERTH: 16:10	As the muscle gets tired.
YUE: 16:13	Right. Yeah.
GERTH: 16:13	And just out of curiosity now, just to finish it off, what did you discover? What was the finding?
YUE: 16:18	Well, the finding was-- so in that particular task, literally your fingers are against the same load for as long as you can. For example, 30% of your maximum load, okay? So you keep doing it as long as you can. In the beginning, you only needed a few motor units to participate in that particular work. But when you get tired, you can see from the screen that shows the firing of the motor unit. And there's more and more motor units jumping in because earlier motor units get tired. And some may cease to fire

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	and some new have to jump in to keep the work going until everyone gets tired, then you have to give up [laughter].
GERTH: 17:14	And then just out of curiosity, because you do a lot of work like this, as the scientist, do you translate that into, "Oh, well, here is an exercise. Here's an exercise routine that would help you fight this problem or help this out"? Do you take it that far or do you just, "Here's the paper. Let somebody else figure out."
YUE: 17:36	Well, some physiological findings, it's difficult to directly apply to your everyday activities. Some you can indirectly related to and some may be directly, but it really depends on what kind of-- so for the motor unit study, so that we understand how the motor units are recruited by the nervous system and how that's affected by fatigue. So we really cannot make a direct application to everyday life. It's difficult. But it improves our knowledge about how the nervous system controls muscles, especially under fatigue conditions, so.
GERTH: 18:22	And then from there you went to the Cleveland Clinic Lerner, right?
YUE: 18:27	Yeah.
GERTH: 18:28	How did you end up there? Did you go directly from the University of Arizona to there or?
YUE: 18:34	Actually, that's another story--
GERTH: 18:36	Oh, please.
YUE: 18:36	So my mentor, Dr. Roger Enoka, he left Arizona. He was actually recruited by Cleveland Clinic to be a faculty member, a full professor. At that time, I had not finished my postdoc program yet, so I went with him together. So that was about two years, really less than two years after I came to his lab. So he moved to Cleveland Clinic in 1993 in the spring. I moved to Cleveland 1993 in September, so like half a year after him because I had to finish some work in Tucson, Arizona. And then so when I arrived at Cleveland Clinic, I was still a postdoc fellow or a research associate, right? And then at that time, I started to write my own grant. And so from 1994, I received the first relatively small grant that can support myself. So the Cleveland Clinic promoted me to, it's called project staff or similar like research assistant professor, okay? So I started working on my own project. And in 1996, Roger Enoka left Cleveland Clinic. He went to the University of Colorado, Boulder because of some family reasons. So he left the clinic. So, also, it's coincident. At the same time, I received my first RO1 NIH grant, 1996.
GERTH: 20:43	Which was the top-level grant. Yeah.
YUE: 20:44	Yeah, RO1. And then basically, the Cleveland Clinic let me take over Roger Enoka's lab [laughter].
GERTH: 20:52	So you lived sort of a charmed life, is what you're saying.
YUE: 20:55	Huh?
GERTH: 20:56	You lived sort of a charmed life.

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YUE: 20:57	Yeah [laughter].
GERTH: 20:58	Yeah, everything seems to happen just at the right time for you to move up.
YUE: 21:01	Right. Yeah. So I have been lucky, I think [laughter]. So then I became a PI, I became an assistant professor because as you said, RO1 is a prestigious award that everybody recognizes. And so that's 1996.
GERTH: 21:24	And then when did you start-- because one of the things I'm very interested in is this work that you did, and I hope I get this right, using mental imagery to strengthen muscles. Because right now as we sit here, I'm working on my six-pack, just thinking about it [laughter]. So tell me about that. How did that come about? That's got to be one of the biggest things you did at the Cleveland Clinic, right?
YUE: 21:46	I think that's one of the things I'm proud of most because the reason I did that, I was taking courses for my graduate studies at Iowa. Then I learned for muscle strength, if you go to a gym and train your muscle, try to get your strength increased-- and there are actually two factors related to or contributing to the strength gain. Actually, the first one is a neuro, so neurofactor, which is how strongly your brain can generate a signal to your muscle. Okay?
GERTH: 22:36	Okay. All right.
YUE: 22:37	Yeah. And the second one is muscle factor, which is you go to the gym and lift heavy weights and your muscle becomes bigger. It's called muscle hypertrophy.
GERTH: 22:51	Right. Right. That's the one I understood. The first one I don't.
YUE: 22:54	And the first one actually is more important.
GERTH: 22:56	Go ahead. Tell me about that.
YUE: 22:57	The first one is more important and actually it's much more important in rehabilitation. So if you could do a voluntary contraction, you cannot generate any force or strength without your voluntary command from your brain to go to your muscle. So this command or this signal, everybody, normal people, for example, this command is always not big enough to recruit all your muscle fibers. There's a big reserve in your muscles, even though you try your hardest.
GERTH: 23:47	So if I'm doing a bicep curl, I've got--
YUE: 23:49	Yeah. Right. If you, for example, lift 50 pounds, for example. You perhaps only use-- even though you try your best effort, you probably only use 50, 60, or maximum 70 percent of your muscles.
GERTH: 24:05	Really?
YUE: 24:05	Right. Because your nervous system is not designed in a way that you can always maximally activate your muscle. There's always a reserve. For athletes, they can do better, but still, they cannot 100%. So that's why if you train yourself to do weights, you can slowly progressively improve your brain's ability to generate a bigger signal to

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	recruit more motor units or more muscle fibers and then you can generate greater force so that really your strength can increase even without muscle change.
GERTH: 24:53	So that's where I get stumped there. So I can increase-- can I increase the size of my muscle?
YUE: 25:01	You can, but the size of muscle increase cannot happen in at least two or three weeks later. There's no way you can change your muscle size like one week or two weeks. Usually, people think it's about at least four to six weeks you can change your muscles.
GERTH: 25:19	So tell me, practically, how do you look at this? How do you--?
YUE: 25:25	So even if you go to do physical training, strength training, the first part of your strength increase, of strength gain is from your nervous system. The improvement of your nervous system to recruit your muscles, to recruit more muscles to participate in the activity.
GERTH: 25:43	So that beyond your muscle getting bigger or how much weight you're lifting, it's not about that, it's about--
YUE: 25:49	It's the nervous system.
GERTH: 25:51	Yeah.
YUE: 25:52	So from that, after I learned that, so I started thinking, "What if I only train my nervous system? Can I get a strength increase?" So that's how I-- I designed the experiment myself and asked people to think about not just your mind, you're watching somebody doing that, but you have to really kind of-- similar like you urge your muscle to contract. Urging, that's a keyword.
GERTH: 26:25	Urge.
YUE: 26:25	Yeah. Urge. If you do correctly-- and my first study showed that in a little-- actually, my first study I turned this little finger muscle here.
GERTH: 26:39	Okay. The little finger.
YUE: 26:40	Because really, because you don't use this very much, so there is a lot of room to improve. So I only trained four weeks. So the average strength increase was 22%.
GERTH: 26:54	And you trained it-- so I've got my hand flat on the table again, and I'm moving my pinky finger away from my other fingers.
YUE: 27:01	Yeah, so just that you think about it. That you have your finger pushing something--
GERTH: 27:03	So you're not actually moving your finger?
YUE: 27:06	No.
GERTH: 27:06	You're just thinking about moving your finger.
YUE: 27:07	So we put an electrode on top of the muscle, make sure that the muscle was not activated.

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GERTH: 27:13	Right. On the side of your hand you're pointing.
YUE: 27:14	Yeah.
GERTH: 27:14	Okay. Right below your pinky finger.
YUE: 27:15	And actually, this is the muscle.
GERTH: 27:16	Yeah. So muscle right below your pinky finger.
YUE: 27:20	Right.
GERTH: 27:21	And so without actually moving it, you're just thinking about what it'd be like to move it. And then, go ahead, what did you discover there?
YUE: 27:29	So there was a 22% increase of the strength after four weeks of training like three times a week. Three times a week and about 15 to 20 minutes each time. So people get more than a 20% increase of strength.
GERTH: 27:49	And did the muscle get any bigger at that point?
YUE: 27:50	No.
GERTH: 27:51	No. But the strength went up that much.
YUE: 27:53	Yeah.
GERTH: 27:53	Wow.
YUE: 27:54	That's a good demonstration of the muscle strength increase from the nervous system without a muscle change.
GERTH: 28:04	And so what did you do with this study? What did you do next then?
YUE: 28:10	Yeah. So later on, so people argue that, "Okay. We see that you had these fantastic results. But can you get this strength increase from other muscles like biceps you use every day?" So we then trained another-- there was another study we compared the strength changes biceps and the same little finger muscle. And we saw actually it's true that we had about-- again it was about four weeks training, we had-- no this is not four weeks. This is a much longer training. So actually, we want to see the slope of this change. I think we had like a 12-week training that was done at Cleveland Clinic. So we saw the biceps-- we had about 16% strength increase after four weeks and then, later on, there was more increase, but it was also attributed to muscles getting bigger. But I--
GERTH: 29:37	It actually got bigger?
YUE: 29:39	Yeah, later.
GERTH: 29:39	Yeah. Yeah.
YUE: 29:40	But the four weeks is not bigger.
GERTH: 29:42	Right.

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YUE: 29:43	For the little finger, it's about the same after four, five weeks. But later on, it increased to about 38% in total. So also, we looked at the muscles, using MRI, looked at muscles. So muscles will get bigger. So this combination of neuro. And also, it showed that the mental training or imagery training can increase not only these little muscle strengths but also bigger muscles you use every day but to a lower extent.
GERTH: 30:19	So this must have made news, right? I mean, people must have been talking about that.
YUE: 30:22	Oh, yeah, the news everywhere. Yeah, I got calls from Germany, from Japan, from everywhere at that time [laughter].
GERTH: 30:29	I spent a few years at Men's Health magazine working there, and I can just like, "Yeah, if I was there during this time, this would be a story."
YUE: 30:36	There was also a request, like newspeople from a foreign country, like I remember from South Korea, they want to fly to the US to [inaudible] [laughter].
GERTH: 30:52	So why aren't you incredibly rich and have a giant mansion somewhere? What happened then with this research? What did you do? Because like you said, you were in the news and this was a pretty cool thing to be able to do.
YUE: 31:08	Yeah, so we tried to apply this to rehabilitation. Because I say all the time that this is really important for rehabilitation because a lot of people who cannot go to the gym and who cannot do high-intensity muscle exercise but they have a healthy brain, they can use their mind to do this mental exercise or mental training to get stronger or at least maintain the muscle condition. So then we did an aging study when I was at Cleveland. That was also support-- I won a grant.
GERTH: 31:48	Yeah. So what was that? What did you do?
YUE: 31:50	Yeah, elderly people can also-- like young people, they can use their mind and increase their strength. And now, actually, there is a cancer weakness study based on a similar idea.
GERTH: 32:05	The whole using your mind--?
YUE: 32:09	Right. So this cancer weakness study [support another hour?] right now. So basically, we ask people to generate low muscle force by applying strong mental effort. So it's [really to use that low level?] because when you always ask people to keep the muscles silent, that's really difficult. But if you allow them to have-- not look at the muscle activity but mainly concentrate on the mind, even though there are some muscle activity but it's okay because everybody can generate some muscle activity as long as it's not too high for a patient, for example.
GERTH: 32:56	So you've been applying this sort of technique to-- and this case it's what we call around here cancer fatigue, right? So it's--
YUE: 33:02	Yeah. No, this is actually for cancer weakness.
GERTH: 33:06	Cancer weakness.

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YUE: 33:07	Yeah.
GERTH: 33:07	Okay. And that's different than fatigue?
YUE: 33:09	Yes, it's different. Yeah.
GERTH: 33:10	Yes, okay. So cancer weakness meaning people are in the throes of cancer or cancer rehab-- is it rehab? Is it what you're working with them or are you working with them during their treatment?
YUE: 33:24	No. Actually, this is an independent study. So we do not collaborate closely with cancer rehab patients or clinics. We just ask them to help us to recruit patients to join our study, so.
GERTH: 33:43	Okay. And so tell me a little bit about that study then. So you're asking them to-- tell me, you're asking them to do essentially exercise with their mind? Is that what you're doing? Do you give them like--
YUE: 33:59	Yeah, similar idea. So the study has three cancer patient groups. One is a control group. You just [test and repeat?] many times.
GERTH: 34:19	Yeah. Just testing their strength.
YUE: 34:20	--without any exercise. So that's a control group. So we just see whether with longitudinal testing, if there's any change. And another group is, I call it a high mental effort group. So they're instructed to-- I think this is elbow flexion.
GERTH: 34:48	Like a bicep curl?
YUE: 34:49	Yeah, bicep. Yeah. So they are instructed to-- it's a handgrip. I'm sorry.
GERTH: 34:55	Oh, handgrip. That's okay.
YUE: 34:56	Handgrip, yeah. It's a handgrip. So they are asked to just casually generate a level of grip so it may generate some-- not more than 30% of maximum force.
GERTH: 35:15	So they're actually squeezing the handgrip--
YUE: 35:16	Yeah. To some extent. So we're not particularly encouraging to just concentrate on-- generally, they're very precise, but as long as you don't go over. But mainly focus on urging the muscle to contract maximally. So this is a complicated process in the nervous system. So first of all, you're only allowed to do this low-level contraction. But there is, on the other hand, your mind trying to generate a very strong signal. It seems complex but you can do it relatively easily once you get used to it.
GERTH: 35:56	And the idea is to train them on how to use their mind to strengthen their body.
YUE: 36:00	Right. So again, urge or urging is a keyword. Otherwise, people sometimes just think, "Oh, I just think [inaudible] [laughter]." You have to work really hard in your mind, so. And this other group is a low mental effort. So they're basically using their muscle to a similar extent, generate a low force. But in the same time, so we present on a TV or computer screen to let them watch TV programs they chose at the beginning. They're interesting, for example. A TV series or a movie or something. So even though they're

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	generating something, but their mind is concentrating on something else they're watching.
GERTH: 36:55	So they're not urging their mind.
YUE: 36:56	They're not. No.
GERTH: 36:57	Yeah. Yeah. Yeah. Okay. Okay. You're distracting--
YUE: 36:59	They're concentrating watching a program that's very interesting. So it has low mental effort related to this particular motor task.
GERTH: 37:08	How did you make the jump to using this as rehab, then when you were there at the Cleveland Clinic, like--?
YUE: 37:17	Well, rehab probably is an area that this idea of this particular research topic can be applied relatively easily and also with wide application. Many neurologic patients and many cancer patients, orthopedic patients, they all have limited ability to doing high-level or high intensity-physical exercises. But they can always use their mind to maintain or improve their muscle strength.
GERTH: 38:02	And then from your past experience and what you think this study is going to bring out, what's the benefit of being able to exercise with this urgentness? What's the benefit then for the patient? How does that help them?
YUE: 38:22	Well, they can maintain their muscle health. The reason the muscle degenerates is you don't use it. And the way you don't use it specifically is the muscles do not receive input from your nervous system. But with this kind of training, the nervous system is sending signals to your muscle. The muscle actually still will [likely?] connect with your nervous system. So the muscle condition will be maintained. Especially for patients, we don't really interestingly ask a patients, "Oh, try to do exercise without the active [inaudible. Make your muscle silent." No, we try to ask them to, just you don't have to exercise your muscle to high intensity that will make you nervous. But just if you can do some level exercise, that's fine. But make sure that you're working hard.
GERTH: 39:25	And someday, do you imagine that there will be a workout? Like for people that can't do any of their lifting at all, you'll have like, "Okay, here, do three reps of thinking about biceps. Do three reps of thinking about--" is that what you imagine this could be someday, is like a whole training program?
YUE: 39:45	Well, for young people, for healthy people, I always suggest them to do you physical exercise as hard as you can because that's how you train both your muscles and your brain to the highest extent. But for patients or people who have limitations to do high-level, high-intensity muscle exercise, keep doing whatever you can with your physical exercise but make sure that you get your nervous system involved in a high level. And then not only then you can maintain your muscle condition or muscle health but also you may be able to improve it. You'll maybe improve your strengths that can help you in many functions, for example, balance. Strength is a major factor of balance.

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GERTH: 40:41	Of balance. Yeah. Yeah. Yeah.
YUE: 40:43	Yeah, or many everyday activities, for example, carry grocery bags and walking the yard, they always require a certain level of muscle strength. So there are many applications.
GERTH: 40:59	That's very cool. And you're still experimenting with it after all these years?
YUE: 41:03	Yeah, sure. Yeah, actually, my next experiment if I get a grant to do this, I'd really want to see what happens in the brain after many weeks of this kind of mental training. How the brain changes and how the connection between brain and muscle changes and how that change correlates with change of the muscle strength. So that's something I really want to do [laughter].
GERTH: 41:32	Okay. I can't wait.
YUE: 41:34	That's a difficult one but it needs to be done.
GERTH: 41:37	Yeah. If you only knew a place that had a giant MRI machine that [laughter]--
YUE: 41:43	MRI, yeah, of course. And also some maybe-- high-density EEG and TMS were doing, all can answer some questions.
GERTH: 41:56	Put it all together. Yeah. Well, because we're talking-- I've made a joke about Kessler having an MRI machine. So let's talk about Kessler here for a second. So you left the Cleveland Clinic after, I think, 18 years, right, to come here to Kessler Foundation. That must have been a little scary. 18 years, I've never had a job for longer than four or five years. So to be somewhere for 18 years-- wait a minute, I think-- yes. I've been married for 18 years just this July. And I'm not planning on changing that because it would just be too many things I'd have to figure out if I changed it. Not to mention I love my wife. How did you come to that decision? How did that come about?
YUE: 42:37	Well, 18 years actually is really long. But I think about-- January next year, I'll be here at Kessler Foundation for eight years.
GERTH: 42:50	For how long?
YUE: 42:50	Eight.
GERTH: 42:51	Eight. Okay.
YUE: 42:52	Yeah. It seems a very short time, it's only eight years [laughter].
GERTH: 42:54	Yeah, it's just eight years.
YUE: 42:56	But the reason I came to Kessler Foundation, first of all, the foundation approached me. The first time I was contacted was by a recruiter. I think somehow I can't remember exactly what happened, but Roger contacted me.
GERTH: 43:17	Rodger the CEO of the Kessler Foundation?
YUE: 43:18	Yeah, Rodger contacted me and asked me whether I would like to come to Kessler Foundation, work at the Kessler Foundation. So I think I came for an interview, I gave a presentation and went back to Cleveland. At that time, when I told Cleveland Clinic

that I was planning to move to New Jersey, Kessler Foundation, and the Cleveland Clinic worked really hard trying to keep me there. They gave a counteroffer, and the department chair, both of medical engineer and PMR, they both met me and asked me what I want and [laughter]--

GERTH: 44:15 So they made it even harder.

YUE: 44:17 Yeah. So that's really hard, a very hard decision because since I had worked at Cleveland Clinic for so long, and the leadership was so-- tried so hard to keep me there, so eventually, so I decided to stay at Cleveland Clinic [laughter]. That was 2009. 2009. So I sent Rodger an email-- I can't remember. It was maybe a letter. And it was so hard. That decision was so hard. And I was very afraid to pick up Rodger's phone call.

GERTH: 45:17 I can imagine. Because you probably thought, "Oh, boy. I have this new guy and he's great."

YUE: 45:22 So the phone has a window that can show the phone number and I'd see the number from Kessler Foundation or Rodger's cell phone. So I even did not pick up [laughter] for many times. For many times.

GERTH: 45:40 So what happened then because you're here now? So you're here.

YUE: 45:43 Yeah. Yeah. So that was 2009.

GERTH: 45:46 So what happened?

YUE: 45:47 So about two years later, 2011, at that time, I almost forgot about Rodgers and the phone numbers. And then one day the phone rang, so I picked up. That was Rodgers [laughter]. That's two years later [laughter]. Oh, boy. So--

GERTH: 46:12 So he had another offer?

YUE: 46:15 Well, he was still asking me to consider Kessler Foundation's position. But as you said previously, many times it's just a coincidence or whatever. Things come together at that time. So the person, the department chair, PMR department chair Cleveland Clinic, my good friend, and he worked with me closely, he left by that time. And the way he left, I was not happy because he was recruited by Cleveland Clinic, gave him a big package to let him build a strong rehab session research program. After three years or something-- yeah, after a few years, he was still in the process of building the program. Actually, I was in charge of that program, the research program. And for some things, political reasons, Cleveland Clinic took back that package and he could not use that resource anymore. So that means that-- and without any reason I know. So he actually was not very-- he was very disappointed and he decided to leave. And I also thought he was lured to Cleveland Clinic. Gave a big package, and then after he came, they took that back. So that's an unethical thing to do. So I was unhappy. At that time, I lost my confidence to Cleveland Clinic. About that time, Rodger's phone call came [laughter].

GERTH: 48:13 You're just a lucky dog. That's all. You're just a lucky guy.

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YUE: 48:17 Yeah, that's when I came to Kessler Foundation [laughter].

GERTH: 48:21 That's great. So your job here then is, I'm going to read it. Director of mobility and rehabilitation engineering research. And that, as we've discussed, I mean, that cuts across a lot of fields. Biomechanics, bioengineer, movement analysis, robotics, neuroimaging. At what point do you think that rehabilitation used to be something and now it's about engineering, isn't it?

YUE: 48:52 Well, yeah, engineering, of course, is a big part of the rehabilitation, medical rehabilitation.

GERTH: 48:59 It wasn't always though, right? It wasn't always about engineering.

YUE: 49:01 Well, it's always there's an engineering component but not as big as now. The times that people-- there's orthotic programs that make artificial limbs, artificial joints, yeah. But now the technology is so much advanced and there are so many new initiatives and advancements and there are so many different assistive devices. Yeah, it's definitely a much bigger component now.

GERTH: 49:45 And it's all interconnected somehow. Isn't it?

YUE: 49:47 Yeah.

GERTH: 49:49 How do you think we're doing with neurological diseases? Are we getting anywhere as far as the rehab goes? Are you seeing improvements? All this engineering, is it helping? And how is it helping?

YUE: 50:09 Yeah. So I think it's all components of rehabilitation including engineering, including activity training, including physiological studies that help understanding the neuromuscular system that makes movement. But I think the big problem now for neurological disorders, we still don't know how this system-- I mean, neuromuscular system, nervous system muscular system, we still don't know how the system after injuries, after disease regenerate and repair. So that's the major obstacle that's preventing people getting quicker and more complete recovery. So that knowledge is still lacking.

GERTH: 51:19 So at this point, I mean, that's kind of what your research is, is trying to figure that out, I guess, is how--

YUE: 51:26 I mean, that part is more like a basic science that I think that many people doing animal research are more specifically looking into that particular question on how the system is regenerated, how the system repairs itself after injury, after disease. For us, we are doing system clinical studies. We try to understand a given technology or a given treatment whether this treatment can improve this particular function better than other treatments. And eventually, we also want to understand if this treatment gives us a better outcome, it's related to better neuroplasticity and nervous system changes that we can see using our MRI machine, using our EEG system, using our TMS system, for instance, so. But labs in our center cannot tell on a basic science level how the cell, like nerve cell or muscle cell change. That's more difficult for us.

GERTH: 52:54 Yeah, you can figure out what's working but you can't say why for sure.

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YUE: 52:57	Yeah. But we can probably say on a system level as a whole. On the brain, on the muscle, on a whole level whether the changes can be correlated with the outcome or with recovery.
GERTH: 53:15	What are some of the things as far as, since you've been here that you're most proud of that your labs have studied?
YUE: 53:20	Yeah, as I said, one of my previous research outcomes is demonstrating that just using your mind can increase your stress. That's probably something I really want to tell people [laughter].
GERTH: 53:40	That's seems like news every time you say it, so that's great.
YUE: 53:43	I still receive the reporters and--
GERTH: 53:48	They're still calling you back?
YUE: 53:49	Yes. They're still calling me about writing something. And another area that I'm excited about is our research related to muscle fatigue or physical fatigue in general. So even though you get physical fatigue due to motor activities, but the fatigue actually has two components. One is cognitive fatigue. One is muscle fatigue. So when I say cognitive fatigue, it's now probably a little bit different than the cognitive fatigue that [inaudible] study. When I talk about cognitive fatigue, it's the muscle lost the ability in the process to recruit muscle-- I mean, the nervous system lost the ability to recruit muscle to participate in the motor activity. So that's also a cognitive component because the central nervous system lost the ability to recruit muscle for the motor activity because that happens at a higher level of the system and also a higher level than even a motor cortex. Motor cortex is a particular brain area that controls the muscle. But above the motor cortex is brain areas that send the signal to motor cortex telling the motor cortex what to do. So even with the physical fatigue, there's a mental part that you lost ability to drive your muscles.
GERTH: 55:49	It's not just that your muscles are tired. It's that your brain, for whether reason, can't recruit them.
YUE: 55:56	Yeah. The next is muscle fatigue itself. So, many patients, when we look at the data, they have fatigue mainly from the nervous system. When they lost the ability to continue the motor activity, when we look at the muscle, the muscle is still relatively unfatigued. The muscle still could generate force. But because the muscle lost the signal from the brain, so there is no driving signal the muscle having stopped.
GERTH: 56:33	Right. Right. Most people, yeah, that will never-- I'll never get tired of thinking about that. That's a perfect place to end. So I think I'll end it right there. Thank you for being with me. I really appreciate you talking to us. [music]
YUE: 56:45	Oh, you're welcome. It's my pleasure.
ANNOUNCER: 56:49	For more information about Kessler Foundation, go to KesslerFoundation.org. Follow us on Facebook, Twitter, and Instagram. Listen to us on Apple Podcast, Spotify, SoundCloud or wherever you get your podcasts.