Creating Caregiving Robots to ...hattacharjee and Dimitropoulou

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SPEAKERS

Dr. Marie McNeely, Dr. Tapo Bhattacharjee, Dr. Katherine Dimitropoulou

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D **Dr. Marie McNeely** 00:01

Hello and welcome to Changing What's Possible: The Disability Innovation podcast brought to you by Cerebral Palsy Alliance Research Foundation or CPARF. I'm your host, Dr Marie McNeely, and this season, we are excited to bring you cutting-edge stories and insights on research, technology, and innovation for people with CP and other disabilities. In most of our full-length Science Spotlight Series episodes, we are highlighting CPARF-funded research. And beyond the folks we fund, there's other interesting, innovative work happening in the CP research space â€" and that's what we'll be focusing on today. Before we introduce you to today's guests, I'd like to take a moment to tell you about 3forCP, CPARF's grassroots fundraising initiative for cerebral palsy research and disability innovation, whether you level up a readathon, a sip and paint event, a comedy show or something else that you love, three for CP gives you the chance to make a difference in your own signature way. Head to 3forCP.org to get started.

D **Dr. Marie McNeely** 00:58

And now we'll get started with today's episode, we have two guests joining us, Dr Katherine Dimitropoulou and Dr Tapomayukh Bhattacharjee. Katherine is an Assistant Professor of Rehabilitation and Regenerative Medicine and the Occupational Therapy Program at the Columbia University Irving Medical Center, and Tapo is an Assistant {rofessor in computer science at Cornell University, and in this episode, we are looking forward to hearing more about Katherine and Tapo, as well as their collaborative work at the intersection of research and technology. So Katherine and Tapo, we are thrilled to have you with us today. How are you both doing today? Perhaps, Katherine, we'll start with you.

D **Dr. Katherine Dimitropoulou** 01:37

Very good. Thank you so very much for the invitation. I'm excited to be here in this podcast.

D Dr. Marie McNeely 01:43

Well, we are thrilled to have you with us. And Tapo, welcome and how are you today?

D Dr. Tapo Bhattacharjee 01:47

Yeah, doing great. Again, thanks for inviting me. I'm super excited to be here.

D Dr. Marie McNeely 01:51

Well, we are looking forward to this conversation, and perhaps we could start with a little bit of background on each of you. So Catherine, maybe take the lead here. Can you tell us a little bit more about yourself.

D Dr. Katherine Dimitropoulou 02:01

So I am full time faculty at Department of occupational therapy at rehabilitation and Regenerative Medicine at Columbia University evening Medical Center, and I'm a research scientist here at the rehabilitation section, and my clinical background is occupational therapy. I've worked for more than 25 years with individuals with your developmental disorders, cerebral palsy, across the lifespan, actually, and other individuals with physical limitations. And I'm very excited and passionate about understanding functional abilities and promoting functionality and participation in everyday life.

D Dr. Marie McNeely 02:42

Phenomenal. I look forward to diving into some of the details of your work in our conversation and Tapo, can you give us some insight into your background as well?

D Dr. Tapo Bhattacharjee 02:50

Absolutely. So. I am an assistant professor in the Department of Computer Science at Cornell University. I work in the area of robotics, specifically assistive robotics. So what I mean by assistive robotics is not like exoskeletons or things like that. Particularly, My lab focuses on robots that are external robots, like robot arms mounted on wheelchairs and things like that. And our lab's goal is to enable these robots to help people with mobility limitations with various activities of daily living. So my lab has done research on robot assisted feeding, robot assisted bathing, and we are also looking at how we can generalize ourselves to even more tasks, such as dressing, transferring and things like that.

D Dr. Marie McNeely 03:34

Oh, wonderful. And Tapo, perhaps you could tell us. How did the two of you get connected? We mentioned in our introduction that you're doing some collaborative research. But where did this

mentioned in our introduction that you're doing some collaborative research. But where did this collaboration begin?

D **Dr. Tapo Bhattacharjee** 03:42

So basically, what happened was, when I was coming to Cornell, I told the people here that for my research to be really successful, I really need stakeholder involvement. And stakeholders is not just potential care receivers and caregivers, but also experts in occupational therapy and rehabilitation, because they are the domain experts, and they would guide what research problems to focus on from our robotics standpoint. So I reached out to some of my senior faculty, and they connected me with Professor Joel Stein, who's basically the head of the department of rehabilitation in Columbia University's Irving Medical Center. He's also involved with couple of other places, so he invited me for a talk, and when I gave the talk there, Katherine was one of the people in the audience. And after that, Catherine reached out, and then we just clicked. We both had similar goals, and so we started collaborating from then on.

D **Dr. Marie McNeely** 04:35

Wonderful and Katherine, is there anything you'd like to add to the story from your perspective?

D **Dr. Katherine Dimitropoulou** 04:40

So when I heard tapos talk, the thing that struck me was this idea of bringing in several voices, voices that actually matter at the design components of assistive technology, especially for activities of daily living, that are very personal, very individual, very curved to each of us, needs and preferences and ideas about how our environment should be or our life should be. So Tapo's work really spoke to my interest in understanding and unpacking the process of functionality with individuals with various limitations. So it was the best idea that I had heard for in a long time.

D **Dr. Marie McNeely** 05:21

I think that's wonderful. I think you both have these complementary interests and backgrounds which really pair nicely for this collaboration. And I know Catherine, you had previously been doing some research on motor planning as well as grasping in people with cerebral palsy. So can you share what have been some of your findings of the work that you're doing in this area?

D **Dr. Katherine Dimitropoulou** 05:39

So my work goes to unpack functionality in multiple levels. So we care to understand the person's interaction with a task, not just evaluating the person or the environment, but actually the interaction of the person while they're carrying out functional tasks. And in that we understand, or we work on unpacking the process of motor actions and how motor actions are decided. How does the person decide to pick up a bottle of water to drink, or how person

decides to set up their environment for them to navigate an activity of daily living, such as dressing or getting out of bed and so forth. So in the work that we have done with motor planning and grasping and reaching, functional reaching, as well as functional walking, it has to do with how does the person gears up or sets up, the decisions that they have to make as they approach different tasks in different environments, from different body positions and their awareness of what they can and cannot do in terms of this particular task. So we have developed metrics in understanding how they plan ahead to approach a task, what their estimates are in terms of what they can and cannot do, when to ask for help, how to integrate that help into accomplishing the tasks they want, and how this process can make them functional and timely in what they want to do with the specific tasks. And we have discovered that there's a lot of gaps in this knowledge in the literature. A lot of the literature focuses on pure motor functioning and muscle health as well as joint health, which is very important, but the integration of those components into how actually someone moves and problem solves through a task is very, very key for them to be able to use whatever abilities they have and maximize them.

D Dr. Marie McNeely 07:33

Certainly, and I know for a condition like cerebral palsy, there's quite a bit of variability in terms of how people experience movement and kind of the symptoms that people may have. How does this variability then factor into how you're studying the motor planning and the problem solving and execution of these movements?

D Dr. Katherine Dimitropoulou 07:49

Yeah, that's a key piece in our work. So we focus on individuals, individuals performance and individuals estimates. So we have created a system where individually, we can identify planning ability as well as decision making for each particular participant in our studies, and then we normalize this across participants so that the individual difference does not get masked is actually taken under consideration when we talk about more Planning and functional execution of the tasks. For example, when someone reaches for a distant target, for picking up a targeted object in their environment, we take into consideration their height, their weight, the range of motion, their spasticity, their constraints, in terms of their decisions, how much do they know about their bodies moving in space and the distances of the targets, and that all comes into a model where we are able to integrate across participants, and our work is reported both on average metrics or means and standard deviations, but also on individual characteristics and individual parameters for each of the participants in the studies.

D Dr. Marie McNeely 09:02

That makes sense. And I know that there are robots that can be assistive in terms of helping people complete movements themselves, but you're working actually in another area, which I think is absolutely fascinating, developing innovative robotic solutions for caregiving, where it's not helping a person do the movement, it's actually completing the movement for them. Tapo mentioned in his introduction this is the sort of robot that would be attached to a wheelchair or

a table or a bedside, something like that, that's basically doing these activities of daily living for them. So can you first, perhaps Tapo describe the gap that currently exists in caregiving that assistive robots could fill?

D Dr. Tapo Bhattacharjee 09:37

Absolutely. There are multiple research groups around the world, and they're working in this area. But how many robots do you actually see in the real world helping people with these activities in their homes or other caregiving settings? Almost zero. The main things to consider here is that, yes, there are some devices like for example, if I consider the ADL of feeding, there are lots of feeding devices. That are there, but they have not been widely adopted as much as we had hoped for, and that is primarily because they have very limited robot autonomy there.

D Dr. Tapo Bhattacharjee 10:09

And let me explain why this is important. So let's imagine there's a robot that wants to help somebody with some task, let's say feeding them or dressing them, or doing various kinds of tasks in their day to day lives. If we want them to help in their homes or in some assisted care environments, our environments are very unstructured, like your kitchen is going to look very different from my kitchen, and my kitchen today is going to look very different from tomorrow and then day after so the key point here is that, how can a robot intelligently generalize its functionality when it can adapt to all of these different unstructuredness and uncertainty in environments. Second thing is, every user is different, and they have different preferences for the kind of care they want to get. So how can a robot adapt to those user preferences and give them the sense of agency. Its purpose is not just have a robot to just help them with these tasks. The purpose is to help them with these tasks while providing them the sense of agency that they need, so that they feel they're in control of their lives. And these are extremely challenging problems. This is the main gap from what's existing. And these are the things that we are working on. We are barely scratching the surface right now, but I think we are taking the first steps towards that direction.

D Dr. Marie McNeely 11:26

Definitely. I think you brought up some really great points, just this idea that the environment is constantly changing, not only between individuals that you have to take into consideration, but within individuals in their own home, like my home, sometimes is very messy, sometimes very clean, and the types of things that I might be cooking or eating would be very different from day to day. So Katherine, is there anything that you'd like to add to this description of the gap that you two are working together to fill?

D Dr. Katherine Dimitropoulou 11:49

Tapo said it excellently. The only thing I would say is, from my point of view, as a clinician and as a researcher for functional ability, it is very individualistic, too. It is really depending on the person's abilities and preferences and how they actually will interact without changing

environment. So solving problems that relate to what really happens in the interaction in the real world, it is much more challenging than just generating technology that is generative and can be put in homes, but not necessarily take under consideration task or person changes and preferences.

D Dr. Marie McNeely 12:28

Absolutely. And I think you've both hinted at some of these challenges that are involved in this idea of having a physical robot caregiver. So you and your colleagues actually recently proposed a new framework called structuring physically assistive robotics for caregiving with stakeholders in the loop, which is a bit of a mouthful, but we'll call it SPARCS for short, to address some of these challenges with fiscal robot caregiving. So Tapo, can you maybe take a stab at first explaining what this framework is and why it was needed.

D Dr. Tapo Bhattacharjee 12:56

based on the same question that I hinted at earlier, which is we started to think, let's take a step back and think, why has there not been any robots that can generalize to arbitrary environments, or users and research translating from lab environments to the real world? So we took a step back and we tried to analyze, what does caregiving involve. To do that, first, we tried to analyze, what does human caregiving involve? So basically, what this work does is we are trying to first identify all the factors that affect caregiving, and then we are trying to come up with a general workflow that can help us define these problems and then translate the technology from lab research to the real world. So the way we are doing this is basically SPARCS has these building blocks, and we consider these building blocks as essential to consider when we actually develop these caregiving solutions. So a building block is the user. When I say user, we mean two kinds of things in the user, the functionality model of the user. What we mean by functionality model of the user is, what is the actual let's say if somebody has a mobility limitation. What is that limitation? Because even people with the same underlying condition can have very different mobility limitations. So first, it's important to understand what is the kind of mobility limitation? What is the severity of the mobility limitation that somebody has, but that just considers functionality.

D Dr. Tapo Bhattacharjee 14:24

We also need another building block, which we call users behavior, which basically means users preferences. For example, somebody wants to eat while watching a baseball game versus somebody wants to eat while sitting with their friends and family in a dining table. And caregiving in both those scenarios are very different. So we considered these building blocks. In addition, we had the environment as a building block. As you pointed out earlier, that environments matter whether I am feeding somebody in a restaurant versus in a home versus in another caregiving setting in a home, also each room, kitchen versus dining room versus bedroom is very different. And the kind of care you give is very different.

D Dr. Tapo Bhattacharjee 15:03

And finally, also comes with the factor that, who is the caregiver? There's a family caregiver

And finally, also comes with the factor that, who is the caregiver? There's a family caregiver. What is their capability? For example, there's a professional caregiver, family caregiver. Can they lift something? And this translates to robot as well. Is the robot heavy enough to lift a person? Can the robot actually move the arm somewhere? So we are considering these building blocks, which we classify as user environment, robot and the human present in this and we try to see that first, we need to characterize each of these functionalities and behaviors of each of these building blocks. Once we have this building blocks, then we want to get stakeholder input to understand how humans currently do caregiving in this scenario for let's say a person X wants to be dressed with a particular shirt while they are lying down. How would a human caregiver provide assistance? So we want to get the inputs from the stakeholders. And the stakeholders are the care receivers themselves, the caregivers, as well as expert occupational therapists and other relevant stakeholders. So once we get all of these inputs from the building blocks, as well as what we call the workflows, we define this as workflows in the sparks paper from the stakeholders, then we as roboticists, can translate this to an equivalent workflow for a robot, like, how would a robot do it, given how we now know how a human does it, and what we need to consider to provide quality care, which is what user aspects we need to consider, what environment factors we need to consider, and once we combine all of this, this will help us come up with a unified framework Using which a robot should be able to provide assistance to a wide variety of users with different mobility limitations and underlying conditions in a wide variety of environments for a wide variety of tasks. That is the basic key idea of SPARCS.

D Dr. Tapo Bhattacharjee 16:55

And I want to quickly say one more thing about SPARCS. If you noticed one thing, what I mentioned is we need to get feedback from the stakeholders. How caregivers actually provide care? Right? Currently, because we want robots to learn from how do we get some feedback? So as a component of sparks, we also developed an app which we are calling SPARCS box, which will release out to the public very soon. And the idea is using this app, we want to invite stakeholders and roboticists into this unified platform so that the occupational therapists, caregivers, care receivers, can actually tell us how they actually provide care. So that's now roboticists know how human caregivers are doing this, so that they can learn from it. So we are also creating an app for robots to be able to learn from the data that we'll receive from the human stakeholders, if that makes sense.

D Dr. Marie McNeely 17:45

Absolutely. I think that's really exciting. And Tapo did a great job of kind of describing all of these different building blocks that you're gathering and breaking down sort of the logic behind the steps that you have to put together for the robots. Katherine, is there anything else that you'd like to add in terms of this framework, and why you think maybe, from a clinical perspective, it was so necessary to develop all of that going into this?

D Dr. Katherine Dimitropoulou 18:06

So the idea of all these components, the building blocks, that went behind sparks, is stemming from the clinical decision making process, where, when we are interacting with individuals that need assistance, or they need a caregivers to support them. In ADL tasks, we train both the caregivers as well as the care recipients into how to best problem solve within their conditions,

their local environments and their local communities, how to problem solve a specific task. So this building blocks that are behind SPARCS framework really reflect pretty much the clinical component of, how do we really analyze the task like the person, the environment, the behavior of the person, the preference of the person, the caregiver process, as well as cognitive and physical components that could interact in the process. And because this was, I think, the very key process of this framework for developing robotics, maybe in contracts to other methods that exist out there, is that it is based on real world feedback at the design phase of the robot, the real problems that have to be solved that each of these building block components as someone is trying to develop a caregiving robot, rather than just developing caregiving robot based on maybe the general perception of what caregiving is. And the thing the second piece that is very important in this process is as SPARCS box develops and feedback from the community now comes in, into all of these parameters, from the care recipients, the caregivers, the variability you mentioned earlier that exists in different physical limitations, conditions in different environments, even in different communities, and caregiving preferences because of culture, because of personal preferences, it can actually be addressed. It can actually be incorporated in the thinking process of developing an assistive device, not after the fact, but before it actually gets to be developed. So I think that's really a change maker in the process of developing assistive devices.

D Dr. Marie McNeely 20:19

That makes sense. Katherine, I really like how you emphasize that this is being developed to solve these real world problems or scenarios that people encounter in the caregiving process. So maybe to help it be more concrete for our listeners, can you walk us through an example of how you could use this SPARCS framework then to design a well defined caregiving scenario that would actually happen in the real world, identify some of the care requirements and then develop an assistive robot solution that would meet that specific need.

D Dr. Katherine Dimitropoulou 20:48

I think this is a two part process at the level of giving feedback or designing a caregiving process and giving feedback into the system through the SPARCS box. One of the things that clinicians and care recipients and their families and or their professional caregivers do is they really go in detail through each of the ADL tasks and understand, for example, in the process of feeding, what is the positioning of the person, what are the distances between the tray of the food to the mouth, what are the types of food the person can eat? What are the preferences in terms of when the person wants to be fed versus not? How are the signs? How is the person communicating with their caregiver, how to proceed in the process of feeding? What are the components that relate to intermediate needs for drinking and or for wiping the mouth, or for being able to talk or being able to signal something in the real world. So those nuances that relate to the building blocks of behavior are really giving very detailed parameters. And the more detailed parameters we can give, the better the robotic process is going to work, and the actual person's physical and cognitive functional abilities, right the body, shape, the structure of their body, their size, their muscle health, any joint limitations. So how much forward can the person lean to get the food? How much tone is there in their neck or in their upper body or in their mouth so that they can receive the food. What is their general neurological signs? Are there always consistent? Do they vary, right? So we're going into the very granular level of actual depicting the physicality of the person as they interacting with the task and the

caregiver. What are their decisions in terms of attention, in terms of cognitive control of their behavior, if something that they hear makes them upset, does it change the feeding process? Does it change the way they will interact with their caregiver? How is that going to be indicated and be stopped and understood? And most of these times, these behaviors in the real world are getting gauged by the caregiver. So it's important to understand what the caregiver looks at when they are trying to read the person's behavior, the person's preferences and intent and habits as they carry out a specific task. So these interactions, as well as the task setup itself, can give us what we call in SPARCS framework, the building blocks that are very detailed, very real world and contextually embedded in the real practice of the person. And I think that that insight is never before given to the roboticists. I mean, Tapo may weigh in on this, but I've never heard of something like this before.

D Dr. Katherine Dimitropoulou 23:40

The second piece is, what we envision is when a robot assistive device gets to be developed through this kind of feedback, or this kind of knowledge of the person, task and caregiver interaction, I think we would have much better ways, or much better results in terms of integrating the robotic assistive device in the process of caregiving, and from a clinical perspective, we would evaluate how well the robot is able to adapt to the natural conditions of the task. But it won't start from scratch. It will start from this background and of knowledge and how well the robotic device can actually complete the task based on the person's intent, cues, preferences and setup of the particular environment and physicality, and then what is the access that a person has and their caregiver to train that robot in the context that they need to use it, so that the robot evolves to become more personalized, more geared to their own needs, and in that way, becomes more integrated to their functional task, rather than the person has to adapt always to what the robotic device can do â€” not the other way around.

D Dr. Marie McNeely 24:50

Certainly and perhaps, Tapo, you could comment on just how unique or maybe innovative this is from a robotics perspective, just having these robots that are personalized and flexible to this extent.

D Dr. Tapo Bhattacharjee 25:00

Yeah, so maybe let me walk you through an example that will help people understand the impact on this. So let's say I live in a particular area, and I'll explain this from two aspects. From a roboticist aspect, a robotics researcher aspect, let's say I have a lab in some place, as a user reached out saying I need some assistance for dressing me in the morning and evening, and I generally have these kinds of shirts and pants or other dresses that I have, and I need some assistance for this. Is there a robot that can help me with this? Now, let's say the roboticists don't have any expertise in the area of how it is done. So how they even build this? So they go to SPARCS box, or this app that I was telling you about, the SPARCS. They go. They can open the app. They can search dressing. The moment they search dressing, they will see a list of people who are working in dressing and the list of other stakeholder inputs of how to dress. For example, a silky shirt on a male or some other dress female, or some other thing. When I say how, they would also see what condition the person has, what mobility limitation the person

has, maybe a video of how a human caregiver is providing this, they will see the list of tasks and annotated tasks like, first lift the right arm. When you lift the right arm, don't hold at the wrist bone, but hold it somewhere in the forearm. Gently lift it to this height, put this cloth here so they will see this entire pipeline. Now that they know this, this is the workflow that I was mentioning for a human caregiving scenario.

D Dr. Tapo Bhattacharjee 26:32

Based on this, now the roboticist would know, "oh, now I know how to solve this." So then the robotics researcher can start working on it. And then when say him, they have a solution. They can not only have this user who reached out to them, they can also put this solution back in this app. Now, let's say in another place, another user wants this solution, they can go to the app, and now they know how to solve this. So that's how. Basically, it's a community driven thing where we care about not only each of these users preferences, and for example, each of the user like, what condition they have, how the care changes, because we have workflows for each user based on their functionality, their preferences, what is the exact activity they're doing, but also a robotic solution for that. So the humans are basically robots. Robotics researchers can learn from each other and can learn from human stakeholders to be able to do it. So think of this as one place where we can find each other's work and then reach out to the correct person to be able to actually deploy this in their life.

D Dr. Marie McNeely 27:31

I think that is so cool. And I can sort of imagine a lot of different ways or different kinds of tasks that these robots could be helping people with. We mentioned specifically eating. We mentioned dressing. Are there other kinds of activities of daily living that you two are envisioning right now that you're designing robots to help people with?

D Dr. Tapo Bhattacharjee 27:49

So first of all, I need to say that each of these tasks are extremely challenging. To even solve one task that can do things reliably in the real world, takes a lot of time. Having said that, we have started delving deep into many of the basic activities of daily living, or core activities of daily living, such as feeding, dressing, transferring somebody from wheelchair to bed or bed to wheelchair, ambulating, as well as bathing. In addition, we have also started looking at some of the other instrumental activities of daily living, like, for example, feeding assumes that meal has been served. Can there be a robot that can help in meal preparation, so things like that, or some other tasks such as in a home, like reaching for a shelf to get a book, or opening doors or things like that. So yes, we have a slew of different projects that are going on in the lab. They have different levels of complexities, but it is still in research phase. It's still going to take time before we can deploy this in the real world, in a wide variety of homes.

D Dr. Marie McNeely 28:44

Absolutely. And Katherine, are there other tasks that you're either working on right now or that you'd hope to work on in the future, in terms of activities of daily living, or things that these robots could be doing for people?

robots could be doing for people?

D Dr. Katherine Dimitropoulou 28:53

I think Tapo covered the majority of the primary tasks, but the idea of figuring out common motor actions that robots can be helpful for, that could generalize to tasks such as crossing the street and being able to press the button to go across and visualizing that as we move this gradually, even one task at a time in the community or in the homes, we will be able to solve navigation, for example, from one room to the other, because you can open the door being able to bring the tray of food with you as you're going to have a meal in the living room. So they're not necessarily other tasks, but it could be also the combination of creating lifestyles or creating habits and routines that are very different and more flexible and more geared towards the person's interests and what they would like to see in their life, rather than having to stay in the kitchen always to eat, because there's no other access to your meal in any other space in your environment, being able to move independently from your kitchen to your bedroom without having to wait for someone to open the door to do it. Eating and while the food is spilled on the floor, being able to actually navigate that without having to wait for someone to come and help you. So it is always thought as tasks, because that's the way to think about and study them and develop them. But in the context of real life, it is lifestyles and habits and choices that people can have that are more flexible and more applicable to what they would like to see in their agency, right being more showcased in those tasks?

D Dr. Marie McNeely 30:32

Definitely. I think these robots have tremendous potential, just from the examples that you described in helping people be more independent, and like you said, have the sense of agency that they can do the things that they want to do in their everyday life. And you mentioned earlier in our conversation that you've been both of you, incorporating feedback and insights from different stakeholders and people with disabilities in your work. Can you talk a little bit more about this process and how you've reached out to people and the kinds of input that you incorporated? Perhaps, Tapo, if you'd like to start.

D Dr. Tapo Bhattacharjee 30:58

Stakeholder engagement is absolutely important, because otherwise, sometimes what happens is us computer scientists, engineers, we tend to invent problems, so it's very important for us to know that the problems that we're solving are really going to be useful at some point in somebody's life. So the way I've done this in my work is basically what happens sometimes, obviously, I reach out to collaborators and ask them if they have connections, and then I meet them and try to tell them that if they would be willing to try out our technologies. But I would say the most successful ones for me have been the following. When we publish these papers, sometimes they get media attention. And then when media publishes this, many people actually reach out and just say, I actually want this robot to help me, or I actually want this robot to help my son or daughter with this task. Can we chat more when we start chatting, obviously, then we understand the scope of what the technology can actually do. That it is not a commercial product yet. It is mostly a research prototype, and we are learning through the process to be able to do this, and then once we get that like basically, it's very important. What I've learned from my experience is to get a few voices or few people who are excited to try out,

and then from their word of mouth, if this happens, it really goes to the other people in the community because they trust otherwise. I'm sure these people are getting emails or calls every week about a new intervention that is happening, and so they are generally skeptical of these new aspects. So that's how I have been reaching out, and some of the specific efforts that I would mention, for example, just last year, with the help of Katherine and also other people that I know, I have been giving talks to not only collaborators in medical schools, but also community organizations, grassroot organizations, and telling them about our work. Through them, I also found out about many different things. So for example, in New York, I think last year, we found out one day where it was known as Disability Advocacy Day, where many people actually went to Albany to voice their issues and their opinions about things. I sent my students there. They went there with different leaflets, and we set up a table, like in some other places and there, and we just go there and we talk to them in the field itself, we have this. Would you be interested in participating? So that's how I have been reaching out. I have also reached out to local caregiving facilities, assisted care environments and things like that. So that has been helpful. And also Katherine has been very, very, very helpful. I let Katherine talk about this, where she has helped us connect to many, many potential care receivers as well. So yeah, these are various efforts that we have been doing. I am also recently starting to reach out to the VA to get some connections there as well. Basically trying to connect anywhere and everywhere possible, to reach out to the people, because without their opinions, our research is hardly of any value.

D Dr. Tapo Bhattacharjee 31:34

Well, I think you are doing amazing work there, spreading the word about your research, and, like you said, building that trust, which I think is so important. And Katherine, do you have additional thoughts on how you two have been kind of getting this feedback and buy in from the community?

D Dr. Katherine Dimitropoulou 33:54

So with the work that I do with Tapo, but also general work that I do with functional abilities, we have created in my lab, what we call networks with local organizations of different levels of access or impacts, and also individuals who actually know us after a while the word of mouth that Tapo mentions, we have personal communications with individuals and their caregivers that have physical limitations and are interested in these studies of functionality, and also the studies with robotics. So we have connections with local organizations that are speaking to communities, more grassroots organizations like the CP Soccer organization, which is in the New York City area, and it works with adolescents with cerebral palsy in a physical activity component. But they also have connections or needs that relate to the other studies that Tapo and I are working on, a network related to ALS or United Spinal and all of these organizations. So we have created what we call a virtual hub, for lack of a better term, where we have frequent interactions with these organizations like Tapo was saying, we participate in events that they do within their communities. We participate or give talks to their stakeholders and things that they may be interested in that relate to managing everyday life as well as managing care as well as robotics.

D Dr. Katherine Dimitropoulou 35:19

I always invite Tapo to come and speak to these communities, because I think his work really supplements and expands what they think the possibilities for action and interaction with the world is. This is a weekly practice for us, and it's not just because of the studies we have. Some stakeholders be co PIs in some of the grants that I have written, participate in common publications scientific and also publications that relate to community understanding of the work. So the idea, or the philosophy, and I think tapo shares this, is that we don't want to wait until this becomes fully developed, whether it's just research and research findings for functionality or research and robotics, but we want the community to participate, give feedback, weigh in and help us integrate or implement this work as soon as it's ready and mature for it.

D Dr. Marie McNeely 36:14

I think that's wonderful, and I know we alluded to throughout our conversation that there are these challenges or barriers to getting this implemented in everyday life. So Catherine, what do you see as some of the biggest challenges, or maybe unanswered questions in robotic caregiving, and how do you personally view this intersection that you're working in of research and technology in this area,

D Dr. Katherine Dimitropoulou 36:32

the biggest hurdle that I've had as a clinician is that we've always had devices that we could prescribe or work with people or bring into people's lives, but those devices had a very short lived duration in their interest, in their applicability, in the way that people were able to utilize it in everyday life. And as an OT I have always problem solved with the caregivers and the individuals on how to best integrate an assistive device, and there's been some success with that, but the problem has always been that after a little while, the person outgrows the device, or the device stops working in the context and the shifts of life and needs of each particular individual, and a lot of the devices were like Tapo was saying earlier, were solving a theoretical problem in their actual development, in their actual functionality, and we had to adapt a lot of the person in the environment to be able to accommodate the device, to be able to do its work, if that makes any sense. And in the world that I envision, or the work that I do with Tapo, the vision is that this is not going to be the case anymore, or this is going to be less of the case anymore, and the challenge will not be of how to make this device work for me, but that this device is actually interacting with me in terms of being able to solve the task.

D Dr. Katherine Dimitropoulou 37:55

And that's a very different potential when it comes to independence and functionality in everyday life for the people we work with. The second challenge is to, I think, the communities have been tired of being left out of the table of the design and things are given to them after it's what I think, too late. And most of the other sectors in technology, you see them really taking under consideration the public's needs, right? The public's opinion, the public's usability of things. The assistive technology sector has not necessarily incorporated the needs of the individual in the first step of the thinking process. And I think the disconnect is big because of that. So I'm hoping, and I think that the work that Tapo is doing is actually really breaking that barrier significantly, and really understands what the persons are actually looking for and are in

need for, and go from there up to developing and solving the problems at the robotic level. That's, for me, the biggest struggle we are in the age of AI and assistive devices have been developing for a long time, but it's so far behind what they can do from what the other sectors of technologies could do for the general public. So it's puzzling to see.

D Dr. Marie McNeely 39:20

Certainly. And Katherine, I really agree with the point that you brought up, that it is so important for people with disabilities and just in general, the end users, to be involved in those early developmental phases of making this kind of technology. And tapo, do you have other challenges or questions that you see as maybe the most pressing in this area?

D Dr. Tapo Bhattacharjee 39:38

I think the most important thing is awareness. Of course, there are lots of technical challenges, like functionally, how to make the robot do all these tasks in in a variety of environments for a variety of users. So I'm not even going to go there. I mean, that is far from being solved. But I think what Katherine has been mentioning is that involving the people for whom the technology is going to be at some point from the beginning. Itself, like using a participatory design process, and not just once you have developed the technology just for evaluation. That is very important. Otherwise it's going to be a paper, but it's not going to be truly useful in somebody's life. I think there are many things, and this is where the awareness thing comes from, because I am learning every day from the stakeholder involvement about what are the right problems to focus on, how to incorporate their views in our research and things like that, but I think as a community, we need to do much more to get this awareness out, because I am not the only assistive robotics researcher in the world. There are many people around the world who are doing this, so there needs to be a general awareness, and people have been becoming more and more cognizant about this, but there needs to be more work done to actually make sure that people don't just focus on the technical and algorithmic aspects of developing a technology, but also actually the user centered aspects of developing the technology.

D Dr. Marie McNeely 40:54

Certainly â€” and I think making the technology truly useful and usable in everyday life is absolutely critical. So Tapo, can you maybe talk a little bit about the process of translation and how you can incorporate some of the findings from the work that you're doing into the real world to help people with disabilities?

D Dr. Tapo Bhattacharjee 41:11

Absolutely yeah, that is a very long term process. I'll try to mostly give you some key insights behind how we are approaching this. So of course, first thing is just involving the stakeholders. We create a team from the beginning itself, right? So let's say, I'm assuming that our problem is defined to make it more grounded. I'm going to even define one problem. But this process is true for every project that we do. But let's say feeding people, like transferring once the robot has picked up a bite from plate, transferring it inside somebody's mouth. Now if you think about

this first, we try to understand what it entails. Given a variety of target population, there are various other derivative conditions that can happen, like in addition to just transferring your food inside somebody's mouth, somebody may have a spasm, somebody may be able to eat only in one side of their mouth. There are, like, lots of interesting, important things. Sometimes while feeding, you know, things may drop, fall off, and wiping is necessary. Sometimes we need to know somebody may have weak bites, and the robot needs to understand when the food has been bitten, so that the robot can get out of the mouth or feeding the next bite. So all of these subtle things that we have to understand that are specific to a particular target population or a particular user that we first have to understand, then for our purpose, of course, we cannot solve the most general problem. It's going to take years to even like do this, we divide it into short chunks. So let's say we want to focus on these three or four sets of target population, and so we are going to target these problems. Once we do that, then what we do is, I work with my students, and we try to develop methods that are needed for a robot to be able to actually do this. Now we have to be really careful about safety. We have to be really careful about doing the task properly while catering to a user's preference. How do we do that? The first step is we try to develop these methods in a digital simulator where, basically in our lab, again, this is a collaboration work with Katherine. We have developed a we call it robotic caregiving simulation world where we have human avatars of people with disabilities. We have avatars of robots. We have assistive environments, hospital beds, wheelchairs and things like that. And we try to simulate this entire scenario and see our if our methods would work in a simulation. In a simulation, of course, safety is not a concern, because these are digital avatars. And of course, in simulation, we try to see what is the force that the robot is exerting when it's trying to feed, what if there is a sudden jerk or a spasm in somebody, or what if they move their tongue, or what if they can eat only in one side of the body? We can simulate all these conditions. We can see what is the force the robot is generating. We can see if the force is safe or comfortable. And then we simulate this. Once we do that, we then what we want to do is we want to translate this to the real world, but we still are not ready to try this with actual people with disabilities and mobility limitations.

D Dr. Tapo Bhattacharjee 44:04

So in between this step, what we did for this particular project was we went to different dentists like, you know, the offices, you know, you dentists have different mouth models with teeth and tongue models and things like that. We got those models, and then I asked my students to actuate it so now this mouth can open and close, and we also attached all kinds of sensors in that mouth. So now think of this as a mouth model, a hardware mouth model with teeth and tongues and sensorized and actuated. So now we try to have a real robot in the real world, because now we are out of the simulator. We have prototyped the solution and simulator and see, can we actually feed this mouth model, and what is the force that we are exerting in these kinds of this sensorized mouth model? Once we have prototyped the solution for that, then what we want to do the next step is we try to try this with people who do not have any mobility limitations, and use them as subjects in our experiment, and try this experiment out with them, and we ask them to simulate all. These conditions, and obviously Catherine and their team that train these students how to simulate properly so that it's realistic, so these people do not have any visible mobility limitations that we know of. These are students at Cornell, and then we try to develop this on that step. Now, once we have tried out all of these three steps and we have developed all the safety modules that are necessary that we think, then only we feel confident that. Okay, now we want to try it with the actual target population, which is our actual goal, and then we try to try this out with them. And then if this works, that's great. If it doesn't work, then

we come back to the whiteboard and do this process again. So that's basically how we do this. This is just an example to ground it for feeding example, but we do this for our other projects as well.

D Dr. Marie McNeely 45:45

Certainly. And I can see how these simulations would be super valuable during this process. And Katherine, would you like to add any comments regarding translation?

D Dr. Katherine Dimitropoulou 45:53

Yeah. So I think that the building blocks that Tapo with my contribution too, but that Tapo and his team has created of SPARCS, as well as the RKR world, provide this kind of steps expedited, right? So you don't have to produce a robot, you know, five times, you just move this robot into gradually developing a more intelligent approach to the task, rather than building and rebuilding, which is cost effective and time consuming and very far away from translation, right? And when you reach the user studies, the actual real world user studies, which we did in the feeding project that Tapo has just described, we were able to feed individuals with schizencephaly, with arthrogryposis, with cerebral palsy, quadriplegia, with tone in the mouth. And interestingly enough, some of these users were able to be fed by the robot much better than their own caregivers. A lot of the tone did not show up. A lot of the bite reflexes did not present themselves during the feeding process. They were very open, very trusting to the robot and actually very excited to be fed. And I think the process of agency has a lot to do with these kinds of behavior and neurological signs of individuals. So getting closer, getting faster, to the real world through these tools that Tapo and his lab have developed, of simulation and SPARCS and these models that he's describing, it's really key, I think, to see the translation happening, not in 20 years from now, but I don't know, in the next five years, maybe for specific actions and for specific components and for specific individuals that have physical limitations. So the idea is, break a little bit this sequence of many, many years in between before something reaches the public into much more flow based on the success of the device and based on those additional tools that help us get to that success with less cost and much more efficiency in time and in the product.

D Dr. Marie McNeely 47:53

Well, Katherine and Tapo, I think this is really exciting research with a lot of potential to help people in their everyday lives, which I think is absolutely wonderful. And if our listeners want to learn more about some of the topics that we talked about today, Katherine, perhaps, can you give them some insight into where they can go or what they can do?

D Dr. Katherine Dimitropoulou 48:10

Our papers are available, obviously, on PubMed, for the scientists out there that are interested. They can find some of my research in my website, and also some of the work that we do in my lab under the pace lab, P-A-C-E at cumc. And we are developing some back end work there to

show some of these experiments, and also some that work more up to date. That's where they can see on my end. Tapo, do you want to speak about yours?

D Dr. Tapo Bhattacharjee 48:40

Sure, Katherine. Basically to find out all these papers or the simulation that we talked about, or even videos of things that we do, or the app that are showing over everything is probably consolidated on my lab website. You'll actually also see Katherine as a collaborator listed in our lab website. So my lab is called EMPRISE Lab, which is E for elephant, M for Mike, P for Paul, R for robot, I for India, S for set and E for elephant. Again, so EMPRISE. So it's m emprise.cs.cornell.edu. You can also find it if you just do a Google search, EMPRISE lab, plus Cornell. And if you go to the Lab website, you will see everything. There are publications, videos, everything else.

D Dr. Marie McNeely 49:23

Thank you both so much for sharing these resources listeners and definitely take some time to check them out to learn more about the amazing work that they're doing. And Katherine, thank you so much for joining us on the show today.

D Dr. Katherine Dimitropoulou 49:35

Thank you very much for the opportunity to talk about all this work.

D Dr. Marie McNeely 49:38

And Tapo, a pleasure to have you here as well. Thank you so much for your time.

D Dr. Tapo Bhattacharjee 49:42

Thank you so much for your invitation. You had great questions. We are happy to share our work with the listeners.

D Dr. Marie McNeely 49:48

Well, it was wonderful to learn more from both of you today and listeners. It's been great to have you with us as well. When you have a moment, please subscribe and leave us a rating and review on your favorite podcast platform to let us know what you think of the show we look forward to connecting with you again in our next episode of Changing What's Possible.