Catherine: Hi, everyone. We have a great conversation today with Joseph Sullivan and Shannon Brady. So we're going to talk about machines and control theory, but also how does that relate to how we manage our emotions, especially as kids. So, um, did you want to introduce yourself? Let's start off with you, Joseph.

Joseph: Yeah. So, um, first, thanks for having me on, uh, the podcast. I'm really looking forward to the conversation. So yeah, my name is Joseph. I'm a soon to be graduating PhD student in my sixth year at the University of Washington. And yeah, in my PhD, I've been studying sort of new design methods, computational design methods for designing robots. And especially what I'm focused on is ways that we can design the dynamics of robots so that they're well suited to the task that we want to use them for. And so yeah, I spend lots of time thinking about the intrinsic dynamical properties of systems and how that interacts with the way we control them, the way that we make them stay safe and stable and behave the way that we want them to. And so that's sort of the direction that I come from. And I think there will be some really cool overlap between dynamical systems and control theory and mental health and the things we'll be talking about.

Shannon: And I'm Shannon Brady. I'm also in my sixth year in my developmental PhD program. So I primarily study children and how they learn about emotions, how they categorize their emotions and the processes that they use to regulate or change their emotions. So I've done work looking at cross-cultural differences, language use, and my dissertation specifically focuses on investigating whether self-talk, the act of talking to ourselves. can be used as a tool to facilitate children's emotion regulation. I'm so excited. Thanks so much for having me.

Jess: Yeah, thank you both. So maybe we can just jump into the overlap that Joseph already brought up of how does dynamical, like what are dynamical systems and what is control theory? And is there an analogy in psychology?

Joseph: Yeah, I can sort of give a little brief outline on like what the engineering and math version of this terminology means. So from the perspective of like engineering, a dynamical system is something that evolves over time. And that the way it evolves over time is deterministic in some sense. And what that means, that determinism means, is that The way that the system will evolve is related to this concept that we call the state, the state of the system. And the state just means it's some information that summarizes the past experience of the system. So in short, a dynamical system is an evolving system where the way it evolves is determined by... a summary of its past experiences. And so to give a couple of concrete, just two concrete examples. So if we think of like the solar system, the solar system is a dynamical system. And we can predict the way that the planets move, at least for a few hundred thousand years or million years or something. But in order to do that prediction, in order to explain how the planets will, where they will be in the future, we need to know at some point in time where are they, what's their position, and also what's their like momentum. And if we know those two things, then we have some, you know, equations Newton's law of gravity from classical physics, or if you're fancy, Einstein's general relativity tells us then, or gives us a way to very accurately predict where the planets will be. tomorrow and the months and years ahead.

And so another more terrestrial example might be a car. Maybe it's an autonomous car, or maybe it's a car with someone driving it. And so for a car, the state will be things like, where is the car on the road? What direction is it heading in and how fast? But then there's also in conjunction with the dynamical systems part, there's also this idea of control inputs and external inputs. That's I think really important to

the conversation. So for a car, there are some environmental factors that determine or partially determine where the car is going to be in the future, how it evolves. So one thing might be the... much water is there on the road? A car drives differently on a wet road than it does on a dry road, or it drives differently on gravel than it does on asphalt. And so that you can think of as like an environmental input. And then there are more control inputs we could call like the steering wheel, the brake pedal, and the accelerator. These are things that like a driver can use to influence. dynamics to determine where the car is going to be or for an autonomous car in the same sense. And so yeah, I just wanted to bring that in. We have this idea of an evolving thing that has state and that the state with maybe some math determines how it will change in time. And then that there are other inputs to the system too from the environment. but also maybe things that are included in the system so that we can influence what it does, the control inputs. Yeah.

So that's a, I think maybe some of the place where we can get into the analogies will be thinking about, you know, for people's, what might be someone's mental state? What are the environmental factors that can influence how our mental states change or our behavior changes in time? And what types of strategies do we have to influence our own? our own dynamics, the dynamics of our mind and our experience.

Shannon: Yeah, so I think it's really interesting when we were discussing this previously, I was shocked because in developmental theory, there's also a dynamic systems theory put forth by Esther Smith and Linda, or sorry, Linda Smith and Esther Thelen. So this theory kind of maps these concepts that Joseph just mentioned onto people, particularly children. So we think of these complex systems like a child's developing mind. as systems that, like Joseph said, evolve over time, they self-organize over time, and there's a lot of emphasis on these environments, whether it's the internal environment, what our bodies are telling us, the external environment and the things, people, and situations that we interact with, and all of those interactions with these different environments continue to provide input. and help the system evolve over time. So there's this emphasis on nonlinear development and an emphasis on how there's less predetermination, I think in the developmental sense of like something big can happen and it's going to put you on a different trajectory just based on that one instance and that one interaction.

JosephThat's super interesting too that you, I was surprised just now to hear the term nonlinear show up because that terminology is also very, very important in the engineering and more abstract math sense. So like, I would like to hear a bit about what nonlinearity means, but just to preempt it. So, from the side that I'm coming from, most dynamical systems are non-linear in the sense that from a control theory perspective, something with linear dynamics is a thing where when you change some input proportionally, so like for my car, if I increase incrementally. how hard I push on the accelerator or how hard I push on the brakes, if that relationship was between those inputs and my dynamics were linear, that means that I would see a proportional change in what the car does. So if I double how hard I push the accelerator, my car would accelerate twice as fast, or if I doubled how hard I push on the brakes, my car would slow down twice as quickly. So I'm wondering, Is the way in which that terminology is used in developmental psychology similar and what might some of the differences be?

Shannon: I think there's a good amount of overlap. I think it really depends on the theory that you come from. There's lots of theories of how development occurs, but there are some that suggest that change, like you said, is incremental. It's like you learn this skill and then you build on it with this skill and then you build on it with this skill. So thinking of cognitive development, like over time, you will gain more

skills and get smarter or more capable cognitively. But in fact, that's not how a lot of development happens. And so we think of development not necessarily as progress or improvement, but change. And those changes can also include regressions or losses of things. So in terms of like how I think developmental psychologists view things as nonlinear. It's that we can go up, we can go back, we can plateau, and it's not going to progress in this consistent moving up, getting better. And it's got a lot more pitfalls. It's not a straight line, I think, is how I describe it.

Joseph: So we're not always, the system isn't always changing in the same direction or going the same way. Yeah, that's very interesting. Slightly different. I think there's a salient difference there for sure. So I'm glad that we cleared that up. Although I think that maybe there is also some commonality there. I get the sense that somebody could have a very nonlinear response. I could have bad things happen to me. I get stuck in traffic and I wait. a long time in line for my coffee or something, and these, you know, maybe have a proportional impact on my mood. But then the next thing is somebody's 15 minutes late to a meeting and like that has pushed me over the edge from having a good day to maybe being on track to having a pretty bad day if I don't make some intervention. So like, in some sense, maybe a lack of proportionality.

Jess: Yeah, and I'm wondering if any of this has to do with what either of you mentioned of just like the different weights, I guess, of like external versus internal aspects that change the state. So like in developmental, like when a child is developing, I imagine that they're like very open to the external world kind of like to determine their state and stuff. And maybe you can expand on that more, Shannon. But then like, yeah, with a robot, like, I assume there's a lot of like internal stuff that's already been pre-programmed. And it's like less environmental. So maybe you can talk to talk about that.

Shannon: Yeah, that's a really great point. And so early on, kids aren't coming in with a lot of previous experience. So most of their interactions are going to be with these like concrete things. So stimuli that they can interact with. So like a little kid. can interact with this Zoom screen that is in front of them right now. But when they leave the Zoom screen, it's gonna be harder for them to like keep that information in their mind because different parts of their development, like neural development, things like that, haven't fully developed. So when you're younger, a lot of the stuff that you're doing and interacting with is that, it's the present, it's very present focused. And a lot of it is just coming from like reactions to things that are happening versus like as we get older, you know, we have this wealth of experience and input that we can kind of build off of. So maybe how you would react to, I don't know, a goal block, like somebody taking your toy when you're five is going to be very different from a similar type of goal block when you're 12, based on all those previous experiences. And what I love about developmental theory is that in consideration with all I just mentioned, it leads to a lot of individual variation. So what Jess might react to and how she might react might be very different from my reactions or what triggers a reaction in me.

Joseph: That's really interesting. So it sounds like from, if I were to try to translate the state, as a mathematician might think about it for a dynamical system, and what's maybe the analogous thing in the developmental psychology for children as they're growing up and gaining these new experiences, the fact that based upon somebody's life experience or their formational experiences, they could have very different responses. to like situations and environmental stimuli that the state is then a really complicated thing. It's like to summarize that whole past experience, it's not really quantifiable. It's really

totally unique and a much longer history that determines how you can predict maybe the way somebody will respond. And that's really, that has some profound implications, I think, from the perspective of control theory. So for like machines, we design them to be really predictable. We design them so that we only have to measure a few things to know what inputs to put in to get them to do what I want. What we might say that the system has like a high degree of observability. And that definitely does not seem to hold in the case of how people develop.

Shannon: Yeah, and I think that that's one thing that developmental psychologists have to contend with and kind of put in their limitations all the time. You know, I can sit here and say, I'm studying how children react to frustrating situations and I can collect all this other information. Like what is... based on their parents' report, how like irritable do they get normally? And I can use that to kind of contextualize. I can think about, do you have siblings? I can think about, you know, SES, all this other stuff, but I'm never going to be able to fully encapsulate, like you said, all of these different past experiences. So I think that, like you said, with a machine, there's a little bit more observability, maybe even a lot more. more controllability because there's somebody kind of from above adding to the information versus with children, especially in addition to like parents, teachers, and other people influencing them, they have a little bit more of an active role in creating their own environment as well. So this like reciprocal interaction also contributes, I think, to even more chaos, even more complexity.

Joseph: It also sounded like basically you said that especially in like early childhood where the children are kind of their behavior and their responses are really driven by the environment and like external stimuli and like the actions of other people. So it sounds like, you know, that maybe they don't have what we would call like control authority. So in the sense that like they don't have much cause effect power over their own life. that, so like if I think about the car, kind of like a car where there's not really an experienced person at the wheel, that it's much more just kind of moving according to the ebbs and bumps in the road. Does that sound right?

Shannon: I think to a certain degree, definitely like more passive in early childhood and infancy as compared to like later childhood, adolescence, adulthood, but something that at least from my perspective that we try to emphasize is that even though they have less control authority, they can still exercise some. So if you wanna compare it to like emotion regulation strategies, if something scary or disgusting and like unpleasant happens and you don't wanna deal with it as an adult, you've got options. You can walk away, you can tell that person to stop doing it, you can like put it away, like you've got options. For an infant, it's harder to exercise that control, but they still have some things they can do. And the best thing they can do is go, I don't wanna look at that. They can still turn their heads, they can close their eyes, they can cry, hopefully someone will understand what they want. So I think humans, essentially, if you wanna say, are programmed with a little bit more controllability, or sorry, control authority over their environments, even if it's not to the same degree as we have when we're essentially fully formed.

Joseph: Yeah, okay, that makes sense. But it seems like maybe instead of having strategies like, you know, I'm not feeling well or I can tell that I'm stressed, I can feel it maybe in my posture or tension in my shoulders saying I'm going to meditate or I'm going to listen to something calming. Whereas for the children, it's more maybe like, oh, I will remove the stimulus that is... making me feel bad or I will signal that I require attention or help from somebody else. So we have like sort of like a coarser, smaller set of

tools. It definitely makes sense to me. I feel like at 33 years old, I have much more, many more strategies at my disposal. averting my eyes and asking people for help is still a big one for sure.

Shannon: And I think that actually brings up a really good point. So there is a developmental progression. When we're younger and we have limited tool sets, we start out with more like distraction, like you're directing your attention away or to things. And then as we get older, I can change my thoughts. I can exercise more control to change my situation. I can change my behavior a little bit more. But this kind of reminds me of the concept of attractor states, which I think has plays roles in both the child dynamic systems theory and also control theory in that depending on who you are, who you interact with, what you learn, all that stuff, you might have some strategies that are just like your go-to. because they're the ones that you know best, even if they might not be the most effective. So I agree, I still will close my eyes when something annoying is happening because I don't wanna look at it. That still works in adulthood, but it can present complications when that's the only thing you know or that's what you tend towards and it might always be effective, right? In some cases, it's gonna work great. In other cases, it might not. So if you have a kid who's, like tendency to react to anger or something displeasing is to like throw a tantrum and like throw everything, kick other people. That's not a great one for them to keep tending towards and be attracted versus, you know, maybe that's why we try to disrupt the system and help them learn these new skills so that they see I have options. And it's like that, yeah.

Joseph: So I guess that the idea of attractor state as it's appearing here, is like maybe sort of a pattern of response to situations and like mechanism for coping when something, some aversive event happens or some aversive stimulus. So I might fall back to throwing a temper tantrum if when I go to the store, my parents won't buy me a new toy or I might you know, when in a difficult social situation, maybe with lots of new people, I might just shell up and not talk and interact much. And that those strategies may work. And in an individual child, we might see them play out many times. But like also they could be not always healthy for the long term development. And so you want to introduce some other like teach children or give them new skills so they can get to a healthier pattern of behavior, healthier attractor, does that sound right?

Shannon: Yeah, and I think a great example of that is, is avoidance of displeasing stimuli, right? Like if there's something really horrible and you don't want to interact with it, the easiest thing to do is avoid. But what you do when that's the thing that you have become accustomed to and then you're an adult and you're anxious about doing your homework, right? In the long term, it's not going to be productive to continue to avoid, avoid. And then maybe you don't turn it in, oh no, now your grades are, ah, this isn't great. So like I said, like teaching new skills and really mapping onto how to be adaptive and like try this other thing, see what works. You want to have a big repertoire. And you also want to make sure that your repertoire's filled with things that you've been able to implement before. Because I know that other people regulate differently and have this, this strategy. But if I've never tried it, and if I've never executed it successfully, it might not be something that I pull to. It's gonna be hiding in the bottom of the toolbox or maybe like broken somewhere.

Catherine: So Joseph, if I was wondering like kind of, to continue the analogy between psychology and machines and engineering, would that be just a software update to whatever machine if it does use a software or a new attachment? And what are the roles of attractor states for machines?

Joseph: Yeah, so that's a really good question. So I guess I will go for the second part first, and then we'll cycle back. So. First, for a dynamical system in general, attractors are something that we see in nonlinear

systems. So nonlinear systems can be more difficult to predict. They can exhibit chaos, which just means that even if you know the state to some finite precision, as time goes on, your ability to predict based upon that observation gets worse. And so maybe people have heard of The Three Body problem because of the great book series and the TV show. It's like a classic example of a chaotic system would be three gravitating bodies. So a lot of nonlinear systems have this built into them. They can be hard to really predict what they're going to do, but nevertheless they have these statistics, these patterns. If you were to look at what their state is over time, you would notice that they tend to congregate in certain areas in the space of states that they could have. And those are usually called attractors. And there may be multiple attractors.

So a system might be, you know, kind of hanging around one attractor, but then there's like a small disturbance or for apparently no reason at all. it just switches to some other attractor state and it sort of hangs around there for some time. And they can go back and forth. But they give us a way to describe the sort of statistical behavior of certain systems. When we go to the control context, so we have some machine that we've built and it has some natural dynamics, but we want to change them using what we usually is something like a feedback. mechanism. What we often try to do is we try to look at where are the dynamics undesirable, where might they lead to like unpredictable behavior or unsafe behavior. So one thing I like to think of is like if you think of trying to balance a ruler on your hand, like a yardstick, you take a yardstick and you try to balance it on your hand, it's not stable in that state. It just wants to fall over and right out of your hand. And you can kind of play this game where you wiggle your hand around constantly trying to move the base of the yardstick beneath its center of gravity to keep it upright. That's like a controller that's taking an unstable point, something that's not safe, and turning it into a stable attractor. So turning it into changing the dynamics so that something that was unsafe or unstable something that's roughly stable, that's an attractor that the system can hang around. And you can be reasonably sure that it's not going to leave.

And yeah, so actually I kind of got lost on what the first part of the question was. But I think that's the strong analogy is that once you get to a control system, you're actually trying to build attractors into a system. by designing a control strategy, a strategy for observing what's happening now and then making some intervention. And so I think the analogy is very strong there to how Shannon described the attractors in psychology.

Catherine: No, yeah, that's totally like, now you nailed it on the head, I believe. Just like, yeah, I was just wondering what the first question's like. Would that be like a software update or here's a new little gear or something for your machine?

Joseph: Yeah, yeah. So for instance, let's say somebody builds a robot. One day somebody is going to build like an anthropomorphic robot that isn't terrible. They haven't accomplished it yet, but people are really trying. And yeah, probably this kind of thing can happen where it's like because the environment is something that we don't. have control over, we don't know everything that's going to happen, we might find out that our coping strategy or control system for our robot works really good in some contexts, but then you put it in this new situation and the controller you have, the strategies you have no longer work. It's not stable. And so you might be like, okay, we need to update what the controller does. We need to switch strategies. When the robot gets into this environment. so that we can make its behavior, its dynamics, predictable and safe and build an attractor where there previously wasn't one, for instance.

Yeah. And that would be like a software update. You'd collect some data and then do some simulations or mathematical modeling and then push that update out to your robot, say, over the internet.

Catherine: And while we were talking about like kind of different strategies for children dealing with problems versus adults, I have a funny story. When I was in grad school, I walked into my lab and there's, so we have this like, I don't know, several tens of thousands of dollars machine called a cryostat that's used to slice brains. And I looked over there. Um, and I just saw on the screen what looked like the word help, like literally, but it was also like not uniform. So it's like a lowercase H a capital E and then like, I think the L was capitalized with the P wasn't. So it's like, maybe this is a weird message. I don't know. I don't mess with the machine, but I just thought it was really funny.

Joseph: But in a sense, please help.

Catherine: The machine is also screaming for help. Like we know probably for most machines, hopefully all, there isn't a sense of awareness in terms of like, like humans have with knowing what state we're in. So I was wondering like, how big is awareness, like a role in regulating your emotions? Because I do feel like some reactions are very instinctive or they're reflexive. Like if I see, I don't know, a... fly coming at me, I'll probably swat it. And like, how does that work with machines as well?

Shannon: Yeah, I think that's a great question. And most people might not like hearing this, but I think there's so much just happening out of our conscious awareness all the time. And it's something that I contend with a lot when studying people's emotions, because I can sit there and ask you, how are you feeling right now? And you might say happy, but based on how you're acting or- you know, what you're saying, I'm like, are you? Right, and some people might not even be aware of their feelings. My lab likes to joke emotions are happening every second all the time. Like right now, if you were to ask me, I'd say probably feel like calm, relaxed, it's like content, like I'm having a good time, but I'm not constantly thinking about what I'm feeling. And so I think that another way to think about it is like, if you come from a more bio background, homeostasis, Right? So are we like chilling, doing okay? Has something like made us go up? Has something made us go down? And has it made it happen to the point that it's like a discernible difference? And sometimes it might be discernible to the outside but not the inside.

So my funny anecdote is for my dissertation, I make kids mad. I give them these very frustrating puzzles and situations. I leave them alone in a room and we record what they say and we can hear them and they're going. Oh, this is so hard. I hate this like curse word curse word. But when you come in and you're like, okay, how did doing that make you feel and they say super-duper happy. And it's, it's very, very interesting. So I maybe this goes a little too far back to a point Joey made about like wanting to make the system safe. I think that with children, it's not about safety in the traditional sense, but it's more about like helping them learn. and this will vary culture by culture, but learning the rules to keep them socially adept, right? So we want them to know what they can and can't do. So maybe kids are telling me, I feel happy after that horrible thing has happened because they've learned not to share their negative emotions with other people. And so while that might not look like the most adaptive or constructive response, it really depends on. is the goal to communicate my feelings accurately and honestly, or is the goal to preserve this interaction that I'm having with another person? And I think that's an interesting place for the machine component to come in because how much are machines, A, having to interact with other machines, I guess it depends on the purpose of the machine, and what are the potential consequences of interacting in an unsafe or unproductive way?

Joseph: Interesting question. And I think this is where we start getting from the engineering side, one, we start getting much closer to psychology. Because so full disclosure, my advisor, a lot of his research and the work a lot of his students do, not that I do, is about trying to understand human machine interaction as a dynamical system, an interaction between two dynamical systems and trying to come up with theories and models of how that evolves. But also in just like the machine-machine case, if we're not talking about humans or beings with like a conscious experience, this is also becoming more important, I think, as we have like all these different systems which are dynamical. I'm thinking like the algorithm that determines the news feed on a social media app, it changes over time and it changes over time based upon how long you watch a given video and what things that you click on. That's like a machine. And that thing also interacts with the ad serving algorithm that is like, I don't know, maybe Facebook talks to Google. And that... these two systems, they give inputs to each other and those inputs change the outputs that they serve out. And this is a really hard emerging area of research. And I think, yeah, we're just scratching the surface on understanding how multiple complex dynamical systems that have their own control strategies interact with each other. And so it's really exciting. And I imagine there are some good lessons to take away from the social interactions and patterns of behavior that you see during the socialization of children when they don't have, you know, maybe as rigid and, and complex of coping mechanisms and strategies or they're not fully socialized.

But yeah, it's hard. This is where things get really tough, I think. And yeah, I see this month by month as my colleagues are meticulously trying to design experiments that shed some light on this. Yeah, great question. I don't know how much I can actually say about it, except that I think it's terribly interesting and fruitful terrain for research.

Jess: Yeah, and something that this conversation has been making me think about is like, for both machines and people, we sort of have like a model, maybe that we're like imposing on the world and being and really like trying to be like, okay, is reality matching my model? And then is, Can we think of emotions as that difference between reality and your model? And likewise, is there something like that for machines? So maybe Shannon's vigorously nodding. Maybe you can go first.

Shannon: Yeah, I think my lab takes the perspective of emotions as information. So there are definitely valid views that sometimes emotions are dangerous. Sometimes they can be harmful, right? Like anger is not great if you're punching somebody in the face. That's not gonna help you or the other person. But the feeling of anger is helpful because it tells you about the status of your goals. Something has happened, now I'm reacting and I feel anger. So this tells me like, I must do something to reestablish that goal that's been blocked for sadness. I might try to do something to reestablish a goal that's been lost. When you're happy, it shows you like, oh, all my goals are being met and I feel... great, or maybe I'm being met over and above my goals. So we think of the emotions, yes, as like telling us where things are with like, maybe our reality, our goals, all the different competing goals, our expectations. And it's kind of telling us like, we're good, everything's okay, oh, something's even better than expected, or like, ooh, something is going very poorly.

Joseph: Yeah. So that's very interesting. So it's kind of like, maybe the subconscious is saying, Hey, I took a measurement of how things are going and it's not great. Our things are good. Keep doing this. Like a message maybe to the conscious experience of things that the conscious mind doesn't have direct access to. And I think we can draw another connection at this point. When I started talking, I talked about state as this thing that like summarizes the past experience and allows you to sort of predict how things are

gonna evolve. And for many, many dynamical systems, like what comes to mind is like a power plant or something. The state is hopelessly complicated and our control system cannot measure everything that it needs to know. to predict exactly what's going to happen. So if I'm generating power, I have a boiler that's pushing water vapor through a turbine. And technically speaking, the state is like, what is every single molecule doing? And you can't possibly know. So you have to build your control strategy. You have to take action with incomplete information. And this part of control theory, this problem, is related to the subject of observability. So when you don't have access to full information, you don't know everything about the state, there are things that you just can't observe or measure. Observability deals with sort of quantifying what are the things that you can infer. from like the sparse or noisy or intermittent measurements that you can make. And yeah, I get the sense, or I guess the analogy I'm trying to draw here is that the emergence of maybe some strongly felt emotion sort of butting into our conscious experience is kind of like a course, maybe like a course. measurement or observation of some underlying process that we actually don't have direct access to, but is a mechanism in some way that we can take that emotion and if we hold it in our mind's eye and inspect it and unpack it, that we can observe more about what is happening beneath the surface, so to speak, beneath the surface of our... conscious experience. And so it may play a very important role in sort of that way for giving us more observability, because our mind and it's just, we're hopelessly complicated.

Shannon: Yeah, it almost makes me think of the subjective experience of an emotion as like an error message. If we're using machine analogies and then like sometimes the error message will be so like stark that you know immediately what's wrong. Other times it might require a little bit more debugging. And I think about this a lot because, and we don't need to get into the whole background into the two camps on emotion theory, Do you feel mad or do you feel like something's wrong and you need to do a little bit more digging because you might dig and find out I feel hurt or I feel disappointed. But if you're just assuming that it's mad right away, your response might not be the most appropriate for a certain situation.

I think about this a lot in romantic couples, right? Like somebody does something a little bit calloused or like inconsiderate and then the other person is like, oh, why'd you do that? Like mad. and creates this fight, but really these feelings are probably stemming from like, do they not care about me? Do they not notice me? I feel hurt, I feel like ignored, I feel lonely, right? So doing a little bit of debugging to find out the source of that error message, I think can be so helpful for people because you don't want to proceed with the assumption that it's a different error and then I think put the system at risk for continuing to. have this error repeat or create new down the line, like bigger ripple effects.

Joseph: Yeah, that's very interesting. And it definitely sounds like an observability type problem. If I were thinking about a machine or a robot or something, and I have some sensors, some things that take measurements, and suddenly I see a discrepancy in my measurement, like I was expecting something, I get something very different, there could actually be a lot of causes potentially. or like why that discrepancy occurs. So the analogy I'm trying to draw is like, I'm experiencing this negative emotion, you know, my face is getting flush, maybe my heart rate's elevated, blood pressure going up a little bit, like tightness in the chest or something. And it's like, okay, is this, this is like anxiety, or this is anger, but what's the cause or what's the correlate? Like what- maybe what's giving rise to it is the thing that you wanna uncover, the thing that you don't directly have access to. For a mechanical system or something that's nice where we have mathematical equations and stuff, the process of doing this is the process of like trying to correlate the discrepancy with the history of measurements that we've taken. And doing

that in a way that's, takes into account a model of what the expected system behavior is. And that's where having internal model of what the system, what you expect the system to behave like becomes really important. Without that internal model, you don't have a good way to correlate these unexpected changes in your measurements with what the potential causes could be. And that might be something interesting us to drill into.

There was another thing that I saw going by us and I just didn't want to leave it behind, which is like you mentioned debugging. And I like that analogy, but like the place that it really resonates with me is that, and where it intersects with observability is, you know, sometimes I think that these processes and these emotional signals just go unacknowledged. We don't hear them. We don't look at them. And eventually, an alarm is going to go off, like a big error message. If any programmers out there who did C++, segfault, kernel panic. And so I had this experience.

I had a kind of, this was happening my fourth year of my PhD. and I was having a lot of anxiety that I hadn't been dealing with for a long time. And there was one like sort of negative experience that I had where I thought I was exposed to like a very dangerous chemical. After this, I developed full-blown panic disorder. So I would just be going about my day, like working with colleagues next to me and somebody would like ask me like a hard question and it wouldn't even phase me. about 45 seconds later, it's like, boom, full fight or flight response, like can't feel my hands, you know, just kind of like losing my... losing the connection between my conscious experience and my physical being just severed. And one of the things that I began to learn through that period, this panic disorder lasted about three months. And there was other things going on, it was like a little health emergency and stuff, but that those panic attacks were often the result of me ignoring things or not being mindful of emotions as I was experiencing them and sort of almost like the signals being ignored, the warning signs being ignored until it becomes like a, yeah, until the bug or the crash report comes up on screen and you know things have gone terribly wrong.

And so yeah, I just wanted to... I thought it was really interesting, because I feel like it really maps onto my own experience in that way and highlights the importance of the mental work we have to do to stay in a healthy state. panic attack is not a healthy state. Yeah. I don't know if that correlates well with your understanding.

Shannon: I definitely think so. I've always been the type who views feelings as, like I said, as information. And when we kind of tamp down or ignore that information, it's like that analogy with the lava bubbling up. It's going to explode. It's going to come out somewhere. So as an emotion regulation researcher, I always tell people like, it might be hard, but it's better to go through the feeling than to avoid or go around the feeling because it's going to manifest in some way, whether it's I'm going to avoid my homework because I don't wanna do it. And then now I'm really stressed out when I'm hanging out with my friends or. I'm sure most PhD students could relate to this. Like when I go home and I'm like, I'm gonna take the day off and then I'm just feeling so guilty about not doing enough work, right? And then I panic, I like panic clean or anxiety clean because it's manifesting in another way. So I think that it might go against the, how do I say this? Like people might think like if I avoid it, if I put it in a box, like it's gone, it's good, I am done.

But- long term, I think the best way to make those go away is to address them when they happen. And it's going to be so hard in that one moment. It's like, how do I say this? Once you've dealt with it, then you can put it down and it'll stay put down. But if you put it down before you've dealt with it, then it's

like, uh-oh, it's going to come back up at random times, like the worst possible times probably. And I think, you know, panic disorder is a little different because it's to a different threshold, but even like regular little anxieties, that's what keeps you up late at night. That's when it's coming out and bothering you or, oh, what if this person thinks of me poorly because of this other interaction that I had in the past that I never dealt with.

Maybe a good example is I have a friend who's looking for jobs and they had a poor parting with an old boss and now they're very, very worried about that having a negative impact on getting a new job. And I said, you know, maybe this is why we could, we could have and should have apologized when that incident happened to not know. But best-case scenario, why don't you reach out now and apologize? Because then at least you can say that you tried and you can put it down and you can move.

Joseph: That's resonating with me a lot. I think that. In my experience, when these strong feelings come up, there's typically two responses that I have. And actually, I think we'll get into your dissertation here very soon because one is that sometimes I just can't deal. And I actually will use self-talk to like divert, to like switch my brain into a different attractor. But then there's other times where, and it's usually when I'm like, maybe getting ready for bed, or I don't have some stimulus to avert myself to, and these things happen. I'm a big believer in when these strong negative feelings coming up, like just leaning right into them, and trying to like pass through, like be with the thoughts. and let them lead where they are going to. When I have the capability of doing that, when I have that degree of freedom, yeah, I find it helps a lot. And so that makes a lot of sense to me. But at the same time, I recognize that I didn't portray self-talk in the best light here, because I think sometimes... Maybe it's, I'm not, it's helpful. It works for me when I don't feel like I have the space and the degree of freedom to lean in to the negative emotion and try to understand what is happening beneath that, what caused it to well up.

But I wanna hear, yeah, your perspective on the role that self-talk can play as this, as maybe a... a feedback mechanism to change our mental processes as a technique for bumping us into a different mental state and what the pros and cons of that might be. Because it's something that I use a lot. And in fact, just really briefly, so I got married in August and I had so much anxiety leading up to the wedding and I also had a lot of other stressors going on. And so when I would, when my mind would go to something, like a negative thought that I just really didn't wanna unpack or deal with, like thinking about an interaction with someone or something I maybe felt like I was neglecting something, I would say to myself, or I would say to my partner, I would say, do you wanna get married? And that like, so for like nine months, this is like an out, it's like a, it's like just a verbal outburst that I have, you wanna get married? And my wife's always like, yes. And now we're married and for two months, I keep saying that, I still have that coping mechanism. And then I go, oh, we already did it. And so I joke with my parents too, they're like, how's married life? And I was like, well, it was a great loss for me because I realized that my coping mechanism no longer makes sense. Yeah, anyway, so anecdote aside, I really wanted to hear what you have to say about and what you've learned in your discovering about self-talk.

Shannon: Yeah, I think it's really interesting the point you make about like when you don't have the room to unpack it. And I think that one, if you just look at the surface, could perceive like, okay, let's not think about that right now as negative, because you're putting your feelings away, but sometimes you have to, right? You can't, well, you could cry at work. Probably shouldn't, I don't know, maybe not. Like I'll cry privately, but you can't like burst into tears in the middle of a meeting. That's not going to be great for you long-term. So I think in those cases, like using the self-talk kind of to kind of be like, I'll come back to

you in a little bit. Like, I'm not gonna put you away forever, but like sometimes we do have to put it to the side. And I feel very affirmed in hearing you say that because to me, that means it's coming out because something hard is happening. Like you're having a big feeling and now you need extra support in the form of this self-talk to kind of get through it. And that's truly what I believe. There's going to be some autonomic or automatic processes that we can engage in when something knocks us off kilter. But sometimes it's going to knock us off so hard that we need extra tools. And when you're a kid, usually that extra tool is your parent, right? Parents are the one who are helping us through big emotions, big tantrums. But sometimes you don't you're not with your mom or like, as an adult, you can't call your mom. My mom's on the East Coast. So if I have a problem after like 6pm, I'm not allowed to call.

So I think that the self-talk can be really helpful, but it depends on how you're using it. So sometimes do negative self-talk of like, Shannon, why'd you do that? But it's not in a way to be like, I hate myself, I'm a big dumb dummy. It's more of like calling attention to a mistake so that I can make it really salient and then never do it again, or at least hopefully never do it again. So for me, I see self-talk as a tool to help direct attention, concretize thoughts in a way that's easier to make sense of them, work through feelings kind of as if you had an imagined person for that social support, and also like help you help yourself through the big feelings that maybe you can't do internally or as automatically.

And I'm seeing a lot of variability in children, which has been fun and interesting. Some kids can't do it even when you ask them to, because it's just not natural for them. Some kids do it even when I haven't asked them to, and they're just talking, which that's how I am. So I'll be interested to see how that relates to physiological stress in response to these situations, how it relates to what they say they feel, and then how age makes a difference. because I think that the nine-year-olds that I'm looking at are gonna be a lot more self-aware about things than the five-year-olds. I think the five-year-olds are the ones who are like, crap, damn it, this is hard, but I'm super-duper happy. Hehehehehe.

Jess: Yeah, something like that this is making me think about too is just like, yeah, some people have really big feels in response to circumstances that they can't control. like, which is not entirely helpful, right? Because it's like, I can't control these circumstances. So like, should I be, you know, doing self-talk then? Should I be like, how do you compartmentalize your emotions in relation to circumstances you can't control or can control? And like, is there, is that like a factor in psychology that changes anything? And then also for machines, you know, like when there's, yeah, if there's an analogy.

Shannon: Yeah, I think control plays a big role in kind of what it makes you experience. And that is kind of what flips us from like one side of the not good to the other side of the not good. So, you know, there's all the not goods, but then there's like angry, sad, scared, and they have different functions. Like anger is my goal is blocked. I must do something about it. Sadness is my goal is lost. I can't do something about it. And fear is like... I'm under threat and then brain stops to kind of ponder a little bit more, I think. So I think when it's uncontrollable, that's when we probably go into sadness. Like I think about grief, right? You can't control if you lose a loved one. That's something that you don't have a lot of control over. Versus anger, sometimes it depends on your situation, but there's usually something you can do, right? Like if somebody is like saying mean things to me, I can be like, stop that. Right? It might not fix the situation. They might keep saying mean things to me, but then I can try a different method of like, I'm going to tell the teacher, or I'm going to punch you in the face, whatever that might be. So I think that sometimes it, it could be that the emotion is kind of giving you insight into the controllability of a situation. And then, even if maybe you have an angry situation that you can't exercise as much control

over. I think about this a lot in the workplace. It's like, if you have a boss, you have to listen to your boss. You can't just tell your boss, like, you suck. I don't like this.

Then I think it becomes about like the secondary processes. What can you do to get yourself from big mad to like a little bit less mad? We don't have to go all the way back down to neutral or all the way over to happy, but you know, any incremental change is going to be helpful, I think. Because over time too, you'll also naturally go from big mad about this to little mad and maybe a new mad about something else. But yeah, you might not be able to control the situation, but you can control or at least try to control your length of staying in that situation and other things.

So we have this strategy called situation modification in... emotion regulation, psychology. So let's say you're home after getting a D on your report card and your parents are really mad at you and you're like, ah, I know this is gonna result in me getting grounded. You tell a joke, like you tell a funny story and like it puts the whole situation in a slightly different light, right? Or if you're like, I can't deal with this, this is too much, you walk away, right? You're changing your situation, even if it be hard to change your thoughts or change your immediate reactions. So I just kind of info-dumped, but I'd love to hear what Joseph has to say about how this could back onto a more machine engineering realm.

Joseph: Well, at first I was thinking about this question, and it seemed like it would be hard to make the connection here at a level deeper than like, okay, self-talk and in the context of like as a tool that you could use maybe. in a situation where you don't have a lot of control, that there might not be much more to it other than, oh, this is a mechanism where a system can have cause-effect power over itself, that it's like a form of feedback. But actually just hearing you talk now, yeah, what it makes me think of is like, for instance, suppose that I have a dynamical system and it's going in some direction. and it doesn't like where that's leading. That that, looking forward, you forecast and you're like, oh, I'm gonna be in a bad place, unstable, not an attractor we want to go to. And so, because when I think about like, or maybe it's gonna be an area where I won't have a lot of control, I won't have a great deal of control if I wind up there. And the self-talk to me feels like a discrete thing. It's abrupt, right? It's like, okay, no, we're changing what we're doing right now. Where the focus is shifting. It's almost like a discontinuity, I feel like in mental state, or at least it feels like it's trying to do that, or at least maybe that's how I use it.

So I think where the analogy comes in is, not to get overly technical, but we have... there's a type of control that we have called bang-bang control. And what bang-bang control is, it's a control policy that goes from one end of the spectrum, one extreme, all the way to the other extreme. And when you use it is when, if your system is headed some way, we're going in some direction that you really don't like. And so you want to get off that course quickly, like as fast as possible. And so you'll be like, okay, we're going to go from, we were just kind of cruising along to like full brakes, left turn, right? Pull the handbrake. And what it's good for is because it acts so fast that it's the quickest way to create a change in what the dynamics are. And... integrated through time over a short period, that means big change in like where you're going to end up, relatively speaking.

And so yeah, that's kind of where I would draw the analogy is I think, personally, I use negative self-talk at times, not always, but as like a bang control. Yeah, it's like, hey, right now, you please don't dwell on the fact that you haven't... emailed the department about scheduling your exam. Like, hey, Melanie, do you want to get married? Oh, I'm already married. Things are great. You know? Yeah, so just to bring it all the way back.

Catherine: So it's kind of like, if I'm getting this correct, like the bang control is like a override or like an emergency shutoff built into the machine itself. It could be.

Joseph: The place where it shows up most is in control problems when you wanna get someplace quickly, really quickly. Time optimal control. So like my objective is to change what the system's doing in the shortest amount of time possible. And you can kind of see how that makes sense because like if each of my degrees of control I have over the system is like a number that has an upper bound and a lower bound. you're just gonna go to one of the extremes. And so that's why they call it bang bang. So like typically like if I have a thing that's in some place and I wanna go to another place, I'm gonna go like full gas until I have all the momentum I need and then I'm gonna go full brakes and then I'm gonna stop right where I... I'm gonna stop at my desired location in the shortest amount of time. But yeah, so... That kind of behavior you could use as like, this is like a fail safe. This is like, oh, we were not expecting things to go this way, but we have just realized that we're about to be in a very unsafe situation. So you use bang bang, you could use bang control policy or turn a bang control policy on to cause an intervention very quickly.

Shannon: And I think that there's a lot of merit in having these bang options. available. And then my brain was like, we have those for emotional situations too. But the danger only comes when we're using the bang option all the time or like way too. You said you saying gas and break reminded me that our bodies react to things. And we have the sympathetic system, which is like step on the gas. And then the parasympathetic, which is like break, break. And when you're like going really high and then really like low, like super quickly that causes a lot of wear and tear on your body as well, like physically and emotionally and all that stuff. So I love the idea of the bang controller as like a failsafe. And I think that that's really important to have like a stop everything. This is what's going to get me back to at least a reasonable state. But yeah, like I think there are some people who tend towards that bang option a lot and it choices.

Joseph: As a controls engineer, it is not my favorite tool in the toolbox. I do not, if I want my robot to do something, I just definitely do not reach for bang control first, maybe last. So yeah, it's, this was a big surprise though to see this overlap. I actually, Shannon, I know we're running out of time, but there's something I really wanted to pick your brain on about self-talk. in your research. And I was wondering that what are the, are there consequences to like the like emotional valence of self-talk? Like I'm thinking of an experiment if I like recorded myself for like two months and did voice to text translation of all of my self-talk and then passed it through like a classifier to give me like the sentiment analysis. know, and like the statistics were, oh man, his self-talk is like, the distribution is very skewed, negative sentiment, or like, you know, the means someplace. Are there, you know, some conclusions we can draw from that, or is there evidence in the literature or in your research that indicates that the emotional valence of self-talk is important?

Shannon: That's a really interesting question. I don't have answers for you yet, but kind of the experiment that you just mentioned is low key what we're doing. We're going to take what kids say, we're going to classify it as first pass, positive, negative, neutral, and then second pass into slightly more nuanced categories. And what I'm hoping to see is to learn a little bit more about like, is it certain types of self-talk that's important? Is it just self-talking in general that's important? Is there a threshold at which the negative self-talk becomes too negative that it's detrimental? I suspect that some negative self-talk is okay, right? If you're using it to call attention to issues, to prevent them from happening, then

that plays a purpose. Like, oops, I shouldn't have done that. Or like, gosh darn it, like, I can't believe I've done this. Versus like, God, you're a big dumb.

So I think about this a lot in psychology of like, are you blaming the situation? Are you blaming the person? And I think if you're just negatively reacting to stuff that's happening, like crap, I dropped this or like, ah, this isn't working, right? That's a situational attribution of like, what's happening. Your self-talk is about what's going on. But if your self-talk becomes like an internal, like I'm dumb, I can't do this, I'm bad. I think that's where we step into this dangerous territory of, I mentioned it can be ruminative, it can wrap us in a loop. So instead of helping us get through the emotion quicker, I think in those cases where it's that extreme, putting those words out loud actually will make the situation worse because you're concretizing that negative experience and almost maybe crystallizing it to a degree that makes it even harder to get out of. So yeah, I think that's interesting. I also am curious to see how much positive self-talk I will have from kids, because these tasks are pulling for negative self-talk probably, because they're frustrating. But sometimes kids will succeed in part of it, and they'll, yes, ooh, I got this, or like, ooh, I can do this, you know?

And I'm curious to see whether that actually will or will not have an effect on feelings, because I think what will be most important is the like, it's okay. as opposed to the like, I can do this. And I think about this a lot in terms of parenting, like your kids having a tantrum, how do you react? You know, you could have the parent that's like, hey, sweetie, what's happening? Let's talk about it. You can have the parent who's like, you're embarrassing me, we're going home. The parent is like, it's not a big deal, stop making a big deal about it. And I'm also asking parents about their self-talk and how they would react to things. So I can try to start, at least hopefully start looking at. how much of what kids produce is similar to what parents would say to them. Like, are we internalizing how our parents talk to us? Cause some kids are very much like, I would tell myself to breathe. And I'm like, that's from your mom. You're five, that's from your mom or your teacher or somebody else. So, so yeah, I don't have the answers yet, but I do think it's gonna be more nuanced than negative self-talk bad, positive self-talk good.

Joseph: And there's also extremes- where it's like, I've experienced this. So one thing is when I started, when my self-talk got really frequent initially, and it was like in the months leading up to that development of panic disorder, I had some like really dark, very like self-abusive bail and self-talk. And it took like maybe like, yeah, two years to kind of like re-bias that. and it's now much more positive and very focused on like, yeah, trying happier things. But this is also not maybe this the kind of self-talk I'm talking about is maybe not the general category, but it's more of this bang kind, like where it's like, it's almost like it's this abrupt utterance. And it's not it's not really like correlated. to like what's happening. So like, you know, the self-talk of like, oh yeah, cool. Or like, damn it. That I might drop an F-bomb while I'm coding at my desk and I can't fix this bug. So yeah, I also, I wonder if there's like, you see those kinds of categories in types of self-talk or like a taxonomy of self-talk.

Shannon: Yeah, I think you're mapping onto the concept of like, is it... because you're explicitly trying to do something, change something, influence something, which it sounds Joseph, that's how more you're using it in this bang way, or is it like a manifestation of the inner thoughts that are happening? And like, I think about offloading a lot, like the cursory like, dang it, it's not working. Sometimes I feel better. I feel better when I let out a curse word, right? Like, and so are those different types of things also going to make a difference? So for example, I'm looking at kids who are saying long-term strategies. Like maybe if I try to find a key that has the same word as the lock, that'll be good. So it's a little bit more explicit.

They're trying to do stuff. Maybe if they're self-talking like, okay, I have to take a deep breath. Like that, how is that going to be different than the offloading self-talk of just like, nope, that didn't work, crap, that didn't work. You know, and hopefully we'll be able to see some differences there as well. I know that we're getting close to time. I'm sure that Jess and Catherine have some things, but I just wanted to throw out a last minute question that I don't think there's an answer to, but I've been thinking about it a lot as we've talked about self-talk. Do you think machines talk to themselves? Not in the conscious way that we do, but like technically, like as they're running, there's probably like bits of information going back and forth, but who's listening other than the machine itself? So this might be too big an abstract of a question, but.

Jess: We were going to take it in that direction too of just like how much can we draw the comparison between humans and machines and do machines have emotions? If emotions are information, if self-talk is like that information being externalized.

Catherine: Yeah, or like are humans more machine-like than we like to admit? And unrelated, but during this conversation I was thinking about kind of partly because we were using a car analogy. You know, the feeling when your check engine light turns on and you're like, uh, the anxiety comes in, but it's kind of like your car's way of like, Hey, something's going on.

Joseph: Yeah, so I don't see this very much. Something tells me that this kind of behavior, it feels like to me, it's like very related to like language and it feels like it's related to this separation between like things that we're consciously aware of and like things that are like bubbling beneath the surface. And so... I'm not a psychologist and I'm not somebody who studies consciousness, but I would suspect that it feels like this has features of this is something that a conscious entity would do. Where might we see it in an unconscious, fully deterministic machine system? Maybe in LLMs? And I think the reason I'd say that or any sort of like... LMs in particular, but language models that have a recurrent nature, one could see that, oh, to get the output they want, maybe they need to access some part of their latent space, and that latent space only can be accessed, or is most easily accessed when a certain token appears in the stream, where you have a recurrent system doing that. So yeah, I think that could be. there could be a similar pattern that emerges there. When you think about LLMs, like their stream of output as a recurrent dynamical system. I haven't played around with chat GPT that much, but I haven't noticed self-talk from chat GPT for instance, but I think I will be looking for it now.

Jess: Yeah. Oh yeah, sorry. Go ahead, Catherine.

Catherine: Yeah, that's really interesting. I mean, I have like used chat GPT to like, especially if I'm stuck in my code. And I do have an automatic, like whatever reason I will just say, oh, thank you. Even though I know you probably aren't alive. I at least hope not. Cause that'd be a little bit weird, but yeah, anyway, anecdote, but Yeah, just in case, right? It's like, if you're alive, I hope you feel better. Smiley face. But we are wrapping up towards an hour and a half. So I was wondering to hear from the both of you, how have you, like what have you learned from each other and how do you think our conversation today will impact your future research going out?

Shannon: I have been... so pleasantly surprised at not only how many overlapping terms there are, and I suspect it's because some psychologists borrowed from control theory, but I think that that's a great insight, right? Like we can take something that was applied mainly to machines and math, and we can try to map it onto human behavior. So I think that there's, it's reminded me that there's a lot of application

of other disciplines in my own. There's a huge merit in talking with other people. And I have just had so many thoughts and ideas about all of these analogies we've come up with, like the debugging, the error message, the software update. I love the software update. It's almost like a child's parents or caregivers are their programmers in a way. And yes, you'll get input from other parts of your environment, other systems, but they're the ones who are kind of putting in the base code that you expand upon. And I think that it's so cool to think about how that has similarities and overlaps with like a programmer and a machine, especially like you said with language learning models. So this has been so fun for me.

Joseph: Yeah, for me as well. This has been a wonderful conversation. I think the biggest takeaway for me is that Shannon, you shared so many things that helped me contextualize a lot of my own behavior and my own past experiences. And I think I can walk away feeling like I have more insight into how my own brain is working and I can feel a little bit better, but also a little bit better about some of my own behaviors, but also more aware of what their function is and maybe how I can tune those control policies that they represent. You know, research wise, my research career is sun setting. So I will be going to industry very soon. However, I think that they're just like how there must have been some fruitful collaboration to percolate dynamical systems and controls ideas into psychology. We're at a very interesting time for collaborations in these two domains.

And yeah, so just to This is not, this is totally selfless plug, but if anyone out there is interested in, you know, collaborating with people who are doing research into trying to quantify the dynamics of human machine interaction and this very hard problem of working with two super complex systems that we can't, we don't fully understand, but nevertheless trying to create some mathematical hypotheses and learn new things about what we can predict for the revolution. Please look up Sam Burden. Please look up his lab at the University of Washington and his graduate students because they're doing really interesting stuff on that front. And I am not involved in any of that research. So this is not a self-plug, I promise. I'm all robots.

Jess: That's actually what we were going to ask as our final thing of just like, is there any of your own stuff, both of you that you would like to share so people can follow you or your work?

Shannon: Yeah, for sure. I'm happy when this is done to send over some of my social media handles. I'm really interested in science communication. And I'm such a nerd when it comes to anything related to emotions. So this is more of a self plug. Yeah, if anyone ever wants to talk feelings wants to talk about like, I think a big thing that I care to do. And I'm so glad Joseph said that he found this to be fruitful, even for himself as an individual is to communicate like more of a research perspective on emotions, because I think that there is a big disconnect between how the research thinks of things and how lay people think of things. And my goal further down the line is to kind of help bridge a little bit of that gap. So love having conversations, casual or formal about feelings.

Jess: Thank you. Anything else from you, Joseph?

Joseph: Yeah, so I guess I would shamelessly tell you guys to go read all my papers, but I'm actually gonna like eject them all like right before I graduate. So you can read my dissertation. If you're interested in new computational design tools for dynamics for robots, that stuff is all coming out, but shout out to my wife. Melanie Anderson and the smell-a-copter. She's a postdoc at UW. Please look up her work. It's very cool and interesting. I also worked a lot on that postbac. It's not related to emotions, but it is biology and engineering and controls.

Jess: Is it a helicopter that smells?

Joseph: It's a drone. Yeah, it has a moth antenna on it and it can smell chemicals in the air and navigate based on those.

Jess: Oh my God. Now this is my field, entomology. Okay.

Catherine: So next episode, Jess.

Joseph: How do you think we got connected?

Jess: Jorge... It was true. It was true. Entomologist. Yes. All right.

Catherine; Well, thanks again for being here both of you. This was a great talk. And yeah, thanks again for being our guests.

Joseph: It was wonderful. Thank you for having me.