# Dr. Erich Jarvis: The Neuroscience of Speech, Language & Music | Huberman Lab Podcast #87

My guest this episode is Dr. Erich Jarvis, PhD—Professor and the Head of the Laboratory of Neurogenetics of Language at Rockefeller University and Investigator with the Howard Hughes Medical Institute (HHMI). Dr. Jarvis' research spans the molecular and genetic mechanisms of vocal communication, comparative genomics of speech and language across species and the relationship between speech, language and movement. We discuss the unique ability of humans (and certain animal species) to learn and communicate using complex language, including verbal speech production and the ability to interpret both written and spoken language. We also discuss the connections between language, singing and dance and why song may have evolved before language. Dr. Jarvis also explains some of the underlying biological and genetic components of stutter/speech disorders, non-verbal communication, why it's easiest to learn a language as a child and how individuals can learn multiple languages at any age. This episode ought to be of interest to everyone interested in the origins of human speech, language, music and culture and how newer technology, such as social media and texting, change our brains.

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Timestamps
00:00:00 Dr. Erich Jarvis & Vocal Communication
00:03:43 Momentous Supplements
00:04:36 InsideTracker, ROKA, LMNT
00:08:01 Speech vs. Language, Is There a Difference?
00:10:55 Animal Communication, Hand Gestures & Language
00:15:25 Vocalization & Innate Language, Evolution of Modern Language
00:21:10 Humans & Songbirds, Critical Periods, Genetics, Speech Disorders
00:27:11 Innate Predisposition to Learn Language, Cultural Hybridization
00:31:34 Genes for Speech & Language
00:35:49 Learning New or Multiple Languages, Critical Periods, Phonemes
00:41:39 AG1 (Athletic Greens)
00:42:52 Semantic vs. Effective Communication, Emotion, Singing
00:47:32 Singing, Link Between Dancing & Vocal Learning
00:52:55 Motor Theory of Vocal Learning, Dance
00:55:03 Music & Dance, Emotional Bonding, Genetic Predispositions

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- Welcome to the Huberman Lab Podcast, where we discuss science and science-based tools for everyday life. [lively music] I'm Andrew Huberman, and I'm a professor of neurobiology and ophthalmology at Stanford School of Medicine. Today, my guest is Dr. Erich Jarvis. Dr. Jarvis is a professor at the Rockefeller University in New York City and his laboratory studies, the neurobiology of vocal learning, language, speech disorders, and remarkably, the relationship between language, music and movement, in particular dance. His work spans from genomics, so the very genes that make up our genome and the genomes of other species that speak and have language such as songbirds and parrots all the way up to neural circuits, that is the connections in the brain and body that govern our ability to learn and generate specific sounds and movements coordinated with those sounds, including hand movements and all the way up to cognition, that is our ability to think in specific ways, based on what we are saying and the way that we comprehend what other people are saying, singing and doing. As you'll soon see, I was immediately transfixed and absolutely enchanted by Dr. Jarvis's description of his work and the ways that it impacts all the various aspects of our lives. For instance, I learned from Dr. Jarvis that as we read, we are generating very low-levels of motor activity in our throat. That is, we are speaking the words that we are reading at a level below the perception of sound or our own perception of those words. But if one were to put an amplifier or to measure the firing of those muscles in our vocal chords, we'd find that as we're reading information, we are actually speaking that information. And as I learned, and you'll soon learn, there's a direct link between those species in the world that have song and movement, which many of us would associate with dance and our ability to learn and generate complex language. So for people with speech disorders like stutter, or for people who are interested in multiple language learning, bilingual, trilingual, et cetera, and frankly for anyone who is interested in how we communicate through words, written or spoken, I'm certain today's episode is going to be an especially interesting and important one for you. Dr. Jarvis's work is so pioneering that he has been awarded truly countless awards. I'm not going to take our time to list off all the various important awards that he's received, but I should point out that in addition to being a decorated professor at the Rockefeller University, he is also an investigator with the Howard Hughes Medical Institute, the so-called HHMI. And for those of you that don't know, HHMI investigators are selected on an extremely competitive basis that they have to re-up, that is they have to recompete every five years. They actually receive a grade every five years that dictates whether or not they are no longer a Howard Hughes investigator or whether or not they can advance to another five years of funding for their important research. And indeed, Howard Hughes investigators are selected not just for the rigor of their work, but for their pioneering spirit and their ability to take on high-risk, high-benefit work, which is exactly the kind of work that Dr. Jarvis has been providing for decades now. Again, I think today's episode is one of the more unique and special episodes that we've had on the Huberman Lab Podcast. I single it out because it really spans from the basic to the applied and Dr. Jarvis's story is an especially unique one in terms of how he arrived at becoming a neurobiologist. So for those of you that are interested

00:03:43 Momentous Supplements

in personal journey and personal story, Dr. Jarvis's is truly a special and important one. I'm pleased to announce that the Huberman Lab Podcast is now partnered with Momentous supplements. We partnered with Momentous for several important reasons. First of all, they ship internationally because we know that many of you are located outside of the United States. Second of all, and perhaps most important, the quality of their supplements is second to none, both in terms of purity and precision of the amounts of the ingredients. Third, we've really emphasized supplements that are single ingredient supplements, and that are supplied in dosages that allow you to build a supplementation protocol that's optimized for cost, that's optimized for effectiveness, and that you can add things and remove things from your protocol in a way that's really systematic and scientific. If you'd like to see the supplements that we partner with Momentous on, you can go to livemomentous.com/huberman. There, you'll see those supplements. And just keep in mind that we are constantly expanding the library of supplements available through Momentous

00:04:36 InsideTracker, ROKA, LMNT

on a regular basis. Again, that's livemomentous.com/huberman. Before we begin, I'd like to emphasize that this podcast is separate from my teaching and research roles at Stanford. It is however, part of my desire and effort to bring zero cost to consumer information about science and science-related tools to the general public. In keeping with that theme, I'd like to thank the sponsors of today's podcast. Our first sponsor is InsideTracker. InsideTracker is a personalized nutrition platform that analyzes data from your blood and DNA to help you better meet your immediate and long-term health goals. I've long been a believer in getting regular blood work done for the simple reason that many of the factors that impact your immediate and long-term health can only be analyzed from a quality blood test. And nowadays with the advent of modern DNA test, you can also get insight into, for example, what your biological age is and compare that to your chronological age. The problem with a lot of DNA tests and blood tests, however, is you get information back about metabolic factors, lipids, and hormones, and so forth, but you don't know what to do with or about that information. InsideTracker solves that problem with a simple platform that allows you to click on any specific factor, learn more about it and what it does in your brain and body, and also the various nutritional supplementation and other types of interventions you can take to bring the levels of that factor into the ranges that are optimal for you and your health. If you'd like to try InsideTracker, you can go to insidetracker.com/huberman to get 20% off any of InsideTracker's plans. That's insidetracker.com/huberman to get 20% off. Today's episode is also brought to us by ROKA. ROKA makes eyeglasses and sunglasses that are of the absolute highest quality. They also have some really unique features that make them especially attractive from the standpoint of aesthetics and performance. The company was founded by two all-American swimmers from Stanford and everything about their eyeglasses and sunglasses were designed with performance in mind. Initially, the eyeglasses and sunglasses were designed for sport, that is for running and for cycling, et cetera. And indeed, still their eyeglasses and sunglasses are very lightweight and they won't slip off your face if you get sweaty, but they also have a terrific aesthetic. You can wear them to work. You can wear them out to eat. I wear readers at night when I work, or if I drive and I wear sunglasses sometimes during the middle of the day, if it's too bright and I need sunglasses in order to see. If you'd like to try ROKA eyeglasses, or sunglasses, you can go to ROKA, that's ROKA.com and enter the code huberman to save 20% off your first order. Again, that's ROKA.com and enter the code huberman at checkout. Today's episode is also brought to us by LMNT. LMNT is an electrolyte drink that has everything you need and nothing you don't, meaning no sugar, but plenty of the correct ratios of sodium, magnesium and potassium, and those three electrolytes, sodium, magnesium, and potassium are critical for your neuron, your nerve cell function, and for the function of all the cells in your brain and body. I've mentioned this before on the podcast, but I'm a fan of salt, not taking too much salt, but certainly not getting too little salt. LMNT has 1000 milligrams, that is one gram of salt, which might sound like a lot of salt. But for many people, especially people who are following low carbohydrate diets, or who are exercising or sweating a lot, or both, that level of salt can actually help you in many circumstances. Getting the appropriate level of salt, and certainly the appropriate levels of electrolytes will improve your cognitive function and will improve your physical performance. If you'd like to try LMNT you can go to drinklmnt, that's lmnt.com/huberman, and you'll get a free sample pack with your order.

00:08:01 Speech vs. Language, Is There a Difference?

That's drinklmnt.com/huberman. And now, for my discussion with Dr. Erich Jarvis. Erich, it's so great to have you here. - Thank you. - Yeah. Very interested in learning from you about speech and language. And even as I ask the question, I realize that a lot of people, including myself, probably don't fully appreciate the distinction between speech and language, right? Speech, I think of as the motor patterns, the production of sound that has meaning, hopefully. And language, of course, comes in various languages and varieties of ways of communicating. But in terms of the study of speech and language, and thinking about how the brain organizes speech and language, what are the similarities? What are the differences? How should we think about speech and language? - Yeah, well, I'm glad you, you know, inviting me here. And I'm also glad to get that first question, which I consider a provocative one. The reason why, I've been struggling, what is the difference with speech and language for many years. And realize, why am I struggling, is because there are behavioral terms, let's call 'em psychologically, psychology developed kind of terms that don't actually align exactly with brain function. All right. And the question is there a distinction between speech and language? And when I look at the brain of work that other people have done, work we have done, also compared it with animal models, like those who can imitate sounds like parrots and songbirds. I start to see there really isn't such a sharp distinction. So, to get at what I think is going on, let me tell you how some people think of it now. That there's a separate language module in the brain that has all the algorithms and computations that influence the speech pathway on how to produce sound and the auditory pathway on how to perceive and interpret it for speech or for, you know, sound that we call speech. And it turns out, I don't think there is any good evidence for a separate language module. Instead, there is a speech production pathway that's controlling our larynx, controlling our jaw muscles that has built within it all the complex algorithms for spoken language. And there's the auditory pathway that has built within it, all the complex algorithms for understanding speech, not separate from a language module. And this speech production pathway is specialized to humans and parrots and songbirds, whereas this auditory perception pathway is more ubiquitous amongst the animal kingdom. And this is why dogs can understand, "sit", "sientese", "come here, boy", "get the ball" and so forth. Dogs can understand several hundred human speech words. Great apes, you can teach them for several thousand,

00:10:55 Animal Communication, Hand Gestures & Language

but they can't say a word. - Fascinating. Because you've raised a number of animal species early on here and because I have a, basically an obsession with animals since the time I was very small, I have to ask, which animals have language? Which animals have modes of communication that are sort of like language. - [Erich] Yeah. - You know, I've heard whale songs. I don't know what they're saying. They sound very beautiful, but they could be insulting each other for all I know. - [Erich] Yeah. - And they very well may be. Dolphins, birds, I mean, what do we understand about modes of communication that are like language, but might not be what would classically be called language? - Yes, right. So, modes of communication that people would define as language, more, very, in a very narrow definition, they would say, production of sound, so speech. But what about the hands, the gesturing with the hands? What about a bird who is doing aerial displays in the air, communicating information through body language, right. Well, I'm going to go back to the brain. So what I think is going on is for spoken language, we're using the speech pathway and all the complex algorithms there. Next to the brain regions that are controlling spoken language are the brain regions for gesturing with the hands. And that hand parallel pathway has also complex algorithms that we can utilize. And some species are more advanced in these circuits, whether it's sound or gesturing with hands and some are less advanced. Now, we, humans and a few others are the most advanced for the speech sounds or the spoken language, but a non-human primate can produce gesturing in a more advanced form than they could produce sound. I'm not sure I got that across clearly, just to say that humans are the most advanced at spoken language, but not necessarily as big a difference at gestural language compared to some of the species. - Very clear and very interesting. And immediately prompts the question, have there been brain imaging or other sorts of studies evaluating neural activity in the context of, you know, cultures and languages, at least that I associate with a lot of hand movement, like Italian. - Yep. - Versus, I don't know, maybe you could give us some examples of cultures where language is not associated with as much overt hand movement. - Yes, so as you and I are talking here today and people who are listening, but can't see us, we're actually gesturing with our hands as we talk without knowing it or doing it unconsciously. And if we were talking on a telephone, I would have one hand here and I'd be gesturing with the other hand. [Andrew laughs] Without even you seeing me, right? And so why is that? Some have argued and I would agree, but based upon what we've seen is that there's an evolutionary relationship between the brain pathways that control speech production and gesturing. And the brain regions I mentioned are directly adjacent to each other. And why is that? I think that the brain pathways that control speech evolved out of the brain pathways that control body movement. All right. And that when you talk about Italian, French, English, and so forth, each one of those languages come with a learned set of gestures that you can communicate with. Now, how is that related to other animals? Well, Cocoa, a gorilla who is raised with humans for 39 years or more, learned how to do gesture communication, learned how to sign language, so to speak, right? But Cocoa couldn't produce those sounds. Cocoa could understand them as well by seeing somebody sign or hearing somebody produce speech, but Cocoa couldn't produce it with her voice. And so, what's going on there is that a number of species, not all of them, a number of species have motor pathways in the brain where you can do learn gesturing, rudimentary language, if you wanted, say with your limbs, even if it's not as advanced as humans. But they don't have this extra brain pathway for the sound. So they can't gesture with their voice

00:15:25 Vocalization & Innate Language, Evolution of Modern Language

in the way that they gesture with their hands. - I see. One thing that I've wondered about for a very long time is whether or not primitive emotions and primitive sounds are the early substrate of language. And whether or not there's a bridge that we can draw between those in terms of just the basic respiration systems associated with different extreme feelings. Here's the way I'm imagining this might work. When I smell something delicious, I typically inhale more. - Hmm hmm. - And I might say, mmm, or something like that. Whereas if I smell something putrid, I typically turn away, and I wince and I will exhale [exhales], you know or sort of kind of like turn away, trying to not ingest those molecules or inhale those molecules. I could imagine that these are the basic dark and light contrasts of the language system. And as I say that, I'm saying that from the orientation of a vision scientist who thinks of all visual images built up in a very basic way of a hierarchical map model of the ability to see dark and light. So I could imagine this kind of primitive to more sophisticated pyramid of sound to language. Is this a crazy idea? Do we have any evidence this is the way it works? - No, it's not a crazy idea. And in fact, you hit upon one of the key distinctions in the field of research that I started out in, which is vocal learning research. So for vocal communication, you have most vertebrate species vocalize, but most of them are producing innate sounds that they're born with producing, that is babies crying, for example, or dogs barking. And only a few species have learned vocal communication, the ability to imitate sounds. And that is what makes spoken language special. When people think of what's special about language, it's the learned vocalizations. That is what's rare. And so, this distinction between innateness and learned is more of a bigger dichotomy when it comes to vocalizations than for other behaviors in the animal kingdom. And when you go in the brain, you see it there as well. And so all the things you talked about, the breathing, the grunting and so forth, a lot of that is handled by the brain stem circuits, you know, right around the level of your neck and below. Like a reflex kind of thing. So, or even some emotional aspects of your behavior in the hypothalamus and so forth. But for a learned behavior, learning how to speak, learning how to play the piano, teaching a dog to learn how to do tricks is using the forebrain circuits. And what has happened is that there's a lot of forebrain circuits that are controlling, learning how to move body parts in these species, but not for the vocalizations. But in humans and in parrots and in some other species, somehow, we acquired circuits where the forebrain has taken over the brain stem and now using that brain stem, not only to produce the innate behaviors or vocal behaviors, but the learned ones as well. - Do we have any sense of when modern or sophisticated language evolved? You know, thinking back to the species that we evolved from, and even within Homo sapiens, has there been an evolution of language? Has there been a devolution of language? [laughs] - Yeah. Yeah, I would say, and to be able to answer that question, it does come with the caveat that I think we humans overrate ourselves compared to other species. And so it makes even scientists go astray in trying to hypothesize when, you especially don't find fossil evidence of language that easily out there in terms of what happened in the past. Amongst the primates, which we humans belong to, we are the only ones that have this advanced vocal learning ability. Now, it was assumed that it was only Homo sapiens, then you can go back in time now based upon genomic data, not only of us living humans, but of the fossils that have been found for Homo sapiens, of Neanderthals, of Denisovan individuals and discover that our ancestor, our human ancestors, supposedly hybridized with these other hominid species. And it was assumed that these other hominid species don't learn how to imitate sounds. I don't know of any species today that's a vocal learner that can have children with a non-vocal learning species. I don't see it. Doesn't mean it didn't exist. And when we look at the genetic data from these ancestral hominids, that, you know, where we can look at genes that are involved in learned vocal communication, they have the same sequence as we humans do for genes that function in speech circuits. So I think Neanderthals had spoken language. I'm not going to say it's as advanced as what it is in humans. I don't know. But I think it's been there for at least between 500,000 to a million years that our ancestors had this ability and that we've been coming more and more advanced with it culturally and possibly genetically. But I think it's evolved sometime

00:21:10 Humans & Songbirds, Critical Periods, Genetics, Speech Disorders

in the last 500,000 to a million years. - Incredible. Maybe we could talk a little bit more about the overlap between brain circuits that control language and speech in humans and other animals. I was weaned in the neuroscience era where birdsong and the ability of birds to learn their tooter song was and still is a prominent field, subfield of neuroscience. And then of course, neuroimaging of humans speaking and learning, et cetera, and this notion of a critical period, a time in which language is learned more easily than it is later in life. And the names of the different brain areas were quite different. If one opens the textbooks, we hear Wernicke's and Broca's for the humans. And you look at the birds of it, I remember, you know. - HVC. - Robustus, striatum. Area X. - That's right. That's right, yes. - Et cetera. But for most of our listeners, those names won't mean a whole lot, but in terms of homologies between areas in terms of function, what do we know? And how similar or different are the brain areas controlling speech and language in say a songbird and a young human child? - Yeah, so, going back to the 1950s or even a little earlier, and Peter Muller and others who got involved in neurotology, the study of neurobiology of behavior in a natural way, right. You know, they start to find that behaviorally, there are these species of birds like songbirds and parrots, and now we also know hummingbirds, just three of them out of the 40-something bird groups out there on the planet, orders, that they can imitate sounds like we do. And so that was a similarity. In other words, they had this kind of behavior that's more similar to us than chimpanzees have with us or than chickens have with them, right, their closer relatives. And then they discovered even more similarities, these critical periods that if you remove a child, you know, this unfortunately happens where a child is feral and is not raised with human and goes through their puberty phase of growth, it becomes hard for them to learn a language as an adult. So there's this critical period where you learn best. And even later on, when you're in regular society, it's hard to learn. Well, the birds undergo these same thing. And then it was discovered that if they become deaf, we humans become deaf, our speech starts to deteriorate without any kind of therapy. If a non-human primate or, you know, or let's say a chicken becomes deaf, their vocalizations don't deteriorate. very little at least. Well, this happens in the vocal learning birds. So there were all these behavioral parallels that came along with a package, and then people looked into the brain. Fernando Nottebohm, my former PhD advisor, and began to discover the Area X you talked about, the robust nucleus of the archipallium. And these brain pathways were not found in the species who couldn't imitate so there was a parallel here. And then jumping many years later, you know, I started to dig down into these brain circuits to discover that these brain circuits had parallel functions with the brain circuits for humans, even though they're by a different name, like Broca's laryngeal motor cortex. And most recently, we discovered not only the actual circuitry and the connectivity are similar, but the underlying genes that are expressed in these brain regions in a specialized way, different from the rest of the brain, are also similar between humans, and songbirds and parrots. So all the way down to the genes. And now we're finding the specific mutations are also similar, not always identical, but similar, which indicates remarkable convergence for a so-called complex behavior in species separated by 300 million years from a common ancestor. And not only that, we are discovering that mutations in these genes that cause speech deficits in humans, like in FOXP2, if you put those same mutations or similar type of deficits in these vocal learning birds, you get similar deficits. So convergence of the behavior is associated with similar genetic disorders of the behavior. - Incredible. I have to ask, do hummingbird sing, or do they hum? - Hummingbirds hum with their wings and sing with their syrinx. - In a coordinated way? - In a coordinated way. There's some species of hummingbirds that actually will, Doug Ashler showed this, that will flap their wings and create a slapping sound with their wings that's in unison with their song and you would not know it, but it sounds like a particular syllable in their songs, even though it's their wings and their voice at the same time. - Hummingbirds are clapping to their song? - Clapping with their, they're snapping their wings together in unison with a song to make it like, if I'm going ba, da, da, da [bangs], but, da [bangs] and I banged on the table except they make it almost sound like their voice with their wings. - Incredible. - Yes. - I, I'm... - And they got some of the smallest brains around. - As the kids would say mind blown, right? - Yes. Yes. - Incredible. - Yes. - Incredible, I love hummingbirds. And I always feel like it's such a special thing to get a moment to see one because they move around so fast and they fled away so fast in these ballistic trajectories. - [Erich] Yep. - That when you get to see one stationary for a moment, or even just hovering there, you feel like you're extracting so much from their little microcosm of life, but now I realize they're playing music essentially. - Right, exactly. And what's amazing about hummingbirds and I'm going to say, vocal learning species in general, is that for whatever reason, they seem to evolve multiple complex traits. You know, this idea that the evolving language, spoken language in particular,

00:27:11 Innate Predisposition to Learn Language, Cultural Hybridization

comes along with a set of specializations. - Incredible. - Yeah. - When I was coming up in neuroscience, I learned that I think it was the work of Peter Muller that young birds learn, songbirds learned their tooter song and learn it quite well, but that they could learn the song of another tooter. In other words, they could learn a different, and for the listeners, I'm doing air quotes here, "a different language", "a different bird song", different than their own species song. But never as well as they could learn their own natural genetically linked song. - Yes. - Genetically linked, meaning that it would be like me being raised in a different culture, and that I would learn the other language, but not as well as I would have learned English. This is the idea. - Yes. - Is that true? - That is true, yes. And that's what I learned growing up as well. And talked to Peter Muller himself about before he passed. Yeah, he used to call it the innate predisposition to learn. All right. So which would be kind of the equivalent in the linguistic community of universal grammar. There is something genetically influencing our vocal communication on top of what we learned culturally. And so there's this balance between the genetic control of speech or a song in these birds and the learned cultural control. And so, yes, if you were to take, you know, I mean, in this case, we actually tried this at Rockefeller later on. Take a zebra finch and raise it with a canary, it would sing a song that was sort of like a hybrid in between. We call it a can-inch, right? [both laughing] And vice versa for the canary, because there's something different about their vocal musculature or the circuitry in the brain. And with a zebra finch, even with a closely related species, if you would take a zebra finch, a young animal, and in one cage next to it placed its own species, adult male, right. And in the other cage placed a Bengalese finch next to it, it would preferably learn the song from its own species neighbor. But if you remove its neighbor, it would learn that Bengalese finch very well. - [Andrew] Fantastic. - It has something to do with also the social bonding with your own species. - Incredible. That raises a question that I, based on something I also heard, but I don't have any scientific peer-reviewed publication to point to, which is this idea of Pidgin not the bird, but this idea of when multiple cultures and languages converge in a given geographic area, that the children of all the different native languages will come up with their own language. I think this was in island culture, maybe in Hawaii, called Pidgin, which is sort of a hybrid of the various languages that their parents speak at home and that they themselves speak. And that somehow Pidgin again, not the bird, but a language called Pidgin, for reasons, I don't know, harbors certain basic elements of all language. Is that true? Is that not true? - I would say, I haven't studied enough myself in terms of Pidgin, specifically, but in terms of cultural evolution of language and hybridization between different cultures and so forth, even amongst birds with different dialects and you bring them together, you know, what is going on here is cultural evolution remarkably tracks genetic evolution. So if you bring people from two separate populations together that have been in their separate populations, evolutionarily, at least for hundreds of generations, so someone's speaking Chinese, someone's speaking English, and that child is then learning from both of them. Yes, that child's going to be able to pick up and merge phonemes and words together in a way that an adult wouldn't, because, why? They're experiencing both languages at the same time during their critical period years, in a way that adults would not be able to experience. And so you get a hybrid. And the lowest common denominator is going to be what they share. And so the phonemes that they've re retained

00:31:34 Genes for Speech & Language

in each of their languages is what's going to be, I imagine, used the most. - Interesting. So we've got brain circuits in songbirds and in humans that in many ways are similar, perhaps not in their exact wiring, but in their basic contour of wiring. And genes that are expressed in both sets of neural circuits in very distinct species that are responsible for these phenomenon we're calling speech and language. What sorts of things are those genes controlling? I could imagine they were controlling the wiring of connections between brain areas. You know, essentially a map of, you know, of a circuit, basically like an engineer would design a circuit for speech and language, nature designed the circuit for speech and language, but presumably other things too. Like the ability to connect motor patterns within the throat of muscles within the throat, or in the control of the tongue. I mean, what are these genes doing? - You're pretty good, yeah. You've made some very good guesses there that makes sense. So, yes, one of the things that differ in the speech pathways of us and these song pathways of birds is some of the connections are fundamentally different than the surrounding circuits, like a direct cortical connection from the areas that control vocalizations in the cortex or the motor neurons that control the larynx, in humans or the syrinx in birds. And so we actually made a prediction that since some of these connections differ, we're going to find genes that control neural connectivity, and that specialize in that function, that differ. And that's exactly what we found. Genes that control what we call axon guidance and form neuronal connections, and what was interesting, it was sort of in the opposite direction that we expected. That is, some of these genes, actually, a number of them that control neural connectivity were turned off in the speech circuit, all right. And it didn't make sense to us at first until we started to realize the function of these genes are to repel connections from forming, so repulsive molecules. And so when you turn them off, they allow certain connections to form that normally would have not formed. So by turning it off, you gain a function for speech, right? Other genes that surprised us were genes involved in calcium buffering neuroprotection, like Parvalbumin or heat-shock proteins, so when your brain gets hot, these proteins turn on. And we couldn't figure out for a long time, why is that the case? And then the idea popped to me one day and said, ah, when I heard the larynx is the fastest firing muscles in the body, all right. In order to vibrate sound and modulate sound in the way we do, you have to control, you have to move those muscles, you know, three to four to five times faster than just regular walking or running. And so when you stick electrodes in the brain areas that control learned vocalizations in these birds and I think in humans as well, those neurons are firing at a higher rate to control these muscles. And so what is that going to do? You're going to have lots of toxicity in those neurons, unless you upregulate molecules that take out the extra load that is needed to control the larynx. And then finally, a third set of genes that are specialized in these speech circuit are involved in neuroplasticity. Neuroplasticity, meaning allowing the brain circuits to be more flexible so you can learn better. And why is that? I think learning how to produce speech is a more complex learning ability than say learning how to walk or learning how to do tricks and jumps and so forth that dogs do. - Yeah, it's interesting as you say that, because I realize that many aspects of speech are sort of reflexive. I'm not thinking about each word I'm going to say, they just sort of roll out of my mouth, hopefully with some forethought. We both know people that seem to speak, think less, fewer synapses between their brain and their mouth than others, right. - Yes. - A lot of examples out there, and some people are very deliberate in their speech,

00:35:49 Learning New or Multiple Languages, Critical Periods, Phonemes

but nonetheless, that much of speech has to be precise. And some of it less precise. In terms of plasticity of speech and the ability to learn multiple languages, but even just one language, what's going on in the critical period, the so-called critical period? - Yeah. - Why is it that, so my niece speaks Spanish. She's Guatemalan and speaks Spanish and English incredibly well. She's 14-years-old. I've struggled with Spanish my whole life. My father is bilingual. My mother is not. I've tried to learn Spanish as an adult. It's really challenging. I'm told that had I learned it when I was eight, I would be better off. - That's right. - Or it would be installed within me. So the first question is, is it easier to learn multiple languages without an accent early in life? And if so, why? And then the second question is if one can already speak more than one language as a consequence of childhood learning, is it easier to acquire new languages later on? - So, the answer to both of those questions is yes, in that, but to explain this, I need to let you know, actually the entire brain is undergoing a critical period development, not just the speech pathways. And so it's easier to learn how to play a piano. It's easier to learn how to ride a bike for the first time and so forth as a young child than it is later in life. What I mean easier in terms of when you start from first principles of learning something. So the very first time, if you're going to learn Chinese as a child versus the very first time you learn Chinese as an adult or learning to play piano as a child versus an adult. But the speech pathways, or let's say speech behavior, I think has a stronger critical period change to it than other circuits. And why, what's going on there in general? Why do you need a critical period to make you more stable, to make you more stubborn, so to speak? The reason I believe is that the brain is not for, the brain can only hold so much information. And if you are undergoing rapid learning to learn, to acquire new knowledge, you also have to, you know, dumb stuff. Put in memory or information in the trash, like in a computer. You only have so many gigabases of memory. And so therefore, plus also for survival, you don't want to keep forgetting things. And so the brain is designed, I believe, to undergo this critical period and solidify the circuits with what you learned as a child and you use that for the rest of your life. And we humans stay even more plastic in our brain functions controlled by a gene called srGAP2. We have an extra copy of it that leads our speech circuit and other brain regions in a more immature state throughout life compared to other animals. So we're more immature. We're still juvenile like compared to other animals. - I knew it. - But we still go through the critical periods like they all do. And now the question you asked about, if you learn more languages as a child, is it easier to learn as an adult? And that's a common finding out there in the literature. There's some that argue against it. But for those that support it, the idea there is, you are born with a set of innate sounds you can produce of phonemes. And you narrow that down because not all languages use all of them. And so you narrow down the ones you use to string the phonemes together, in words that you learn and you maintain those phonemes as an adult. And here comes along another language that's using those phonemes or in different combinations you're not used to. And therefore, it's like starting from first principles, but if you already have them in multiple languages that you're using, then it makes it easier to use them in another third or fourth language. - I see, incredible. - So, it's not like your brain has maintained greater plasticity, it's your brain has maintained greater ability to produce different sounds that then allows you to learn another language faster. - Got it. Are the hand gestures associated with sounds or with meanings of words? - I think the hand gestures are associated with both the sounds and the meaning. When I say sound like if you are really angry, right, and you are making a loud screaming noise, right, you may make hand gestures that look like you're going to beat the wall, right? Because you're making loud sounds and loud gestures, right. But if you want to explain something like, come over here, what I just do now to you for those who can't see me, I swung my hand towards you and swung it here to me. That has a meaning to it, to come here. So just like with the voice, the hand gestures are producing both, you know, both qualities of sound. - And for people that speak multiple languages, especially those that learn those multiple languages early in development, do they switch their patterns of motor movements according to let's say, going from Italian to Arabic or from Arabic to French in a way that matches the precision of language that they're speaking? - You know what? You just asked me a question, I don't know the answer to. I would imagine that would make sense because of switching in terms of sometimes people might call this code switching, even different dialects of the same language. Could you do that with your gestures? I imagine so, but I really don't know if that's true or not. - Okay, well, I certainly don't know from my own experience

00:41:39 AG1 (Athletic Greens)

because I only speak one language. [both laughing] Before we continue with today's discussion, I'd like to just briefly acknowledge our sponsor, Athletic Greens, now called AG1. Athletic Greens, aka AGI, is an all-in-one vitamin mineral probiotic drink that also has adaptogens and digestive enzymes. I've been taking Athletic Greens since way back in 2012 so I'm delighted that they're sponsoring the podcast. The reason I started taking Athletic Greens and the reason I still drink Athletic Greens twice a day is that it supplies total foundational coverage of my vitamin mineral needs and it supplies important nutrients that I need to support my gut microbiome. The gut microbiome, as many of you know, supports the immune system and it also supports the so-called gut brain access, which is vital for mood, for energy levels, for regulating focus and many other features of our mental health and physical health that impact our daily performance and high performance in any endeavors we might be involved in. If you'd like to try Athletic Greens, you can go to athleticgreens.com/huberman and claim a special offer. They're giving away five free travel packs, plus a year's supply of vitamin D3 K2 with every order. And of course, vitamin D3 K2 are vital for all sorts of things like hormone health and metabolic health

00:42:52 Semantic vs. Effective Communication, Emotion, Singing

and K2 for cardiovascular health and calcium regulation. Again, you can go to athleticgreens.com/huberman to claim that special offer. To go a little bit into the abstract, but not too far, what about modes of speech and language that seem to have a depth of emotionality and meaning, but for which it departs from structured language. Here's what I mean, poetry. - Hmm hmm. - I think of musicians, like there's some Bob Dylan songs that, to me, I understand the individual words. I like to think there's an emotion associated with it. at least, I experience some sort of emotion and I have a guess about what he was experiencing. But if I were to just read it linearly without the music and without him singing it, or somebody singing it like him, it wouldn't hold any meaning. So in other words, words that seem to have meaning, but not associated with language, but somehow tap into an emotionality. - Yep, absolutely. So, we call this difference semantic communication, communication with meaning and effective communication, communication that has more of an emotional feeling content to it, you know, but not with, you know, the semantics. And the two can be mixed up, like with singing words that have meaning, but also have this effect of emotional, you just love the sound of the singer that you're hearing. And initially, you know, psychologists, scientists, in general, thought that these were going to be controlled by different brain circuits. And it is the case. There are emotional brain centers in the hypothalamus, in the cingulate cortex and so forth, that do give tone to the sounds. But I believe, you know, based upon imaging work and work we see in birds, when birds are communicating semantic information in their sounds, which is not too often, but it happens, versus effective communication, sing because I'm trying to attract the mate, my courtship song or defend my territory, it's the same brain circuits. It's the same speech-like or song, circuits are being used in different ways. - A friend of mine, who's also a therapist, said to me, you know, it's possible to say, I love you with intense hatred than to say, I hate you with intense love. - [Eric] Right. - And reminding me that it's possible to hear both of those statements in either way. So I guess it's not just limited to song or poetry. It also, there's something about the intention and the emotional context in which something spoken that it can heavily shape the way that we interpret what we hear. - That's right. And I consider all of that actually, meaning, even though I defined it as, people commonly do semantic and effective communication. Effective communication to say, I hate you, but meant love, right, does have emotional meaning to it, you know? And so, you know, one's more like an object kind of meaning or an abstract kind of meaning. There's several other points here I think it's important for those listening out there to hear is that when I say also this effective and semantic communication being used by similar brain circuits, it also matters, the side of the brain. In birds and in humans, there's left-right dominance for learned communication, learned sound communication. So the left in us humans is more dominant for speech, but the right has a more balance for singing or processing musical sounds as opposed to processing speech. Both get used for both reasons. And so when people say your right brain is your artistic brain and your left brain is your thinking brain, this is what they're referring to. And so that's another distinction. A second thing that's useful to know is that all vocal learning species use their learned sounds for this emotional effective kind of communication, but only a few of them like humans and some parrots and dolphins use it for the semantic kind of communication, we're calling speech. And that has led a number of people to hypothesize that the evolution of spoken language, of speech, evolved first for singing, for this more like emotional kind of mate attraction like the Jennifer Lopez, the Ricky Martin kind of songs and so forth. And then later on, it became used for abstract communication

00:47:32 Singing, Link Between Dancing & Vocal Learning

like we're doing now. - Oh, interesting. Well, that's a perfect segue for me to be able to ask you about your background and motor control, not only of the hands but of the body. So you have a number of important distinctions to your name, but one of them is that you were a member of the Alvin Ailey Dance School, School of Dance. - That's right. That's right, hmm hmm. - So you're an accomplished and quite able dancer, right? Tell us a little bit about your background in the world of dance and how it informs your interest in neuroscience, [clears throat], excuse me, and perhaps even how it relates specifically to your work on speech and language. - Yes, well, it's interesting. And then this kind of history even goes before my time. So in my family, my mother and father's side, they both went to the High School of Music and Art here in New York City. And particularly, in my mother's family, going back multiple generations, they were singers. And I even did my family genealogy and found out not only, you know, we have some relationships to some well-known singers, distant relationships like Thelonious Monk, but going back to the plantations in North Carolina and so forth, my ancestors were singers in the church for the, you know, the towns and so forth. And this somehow got passed on multiple generations to my family. And I thought I was going to grow up and be a famous singer, right. And me and my brothers and sister formed a band when we were kids and so forth. But it turned out that I didn't inherit the singing talents of some of my other family members, even though, you know, I was, you know, okay. You know, but not like my brother, or not like my mother or my aunts and my cousin Pura Fe', who's now a talented Native American singer. And so, that then influenced me to do other things. And I started, you know, competing in dance contests, you know, actually this is around the time of Saturday Night Fever and I was as a teenager. And I started winning dance contests. And I thought, oh, I can dance. And I auditioned for the High School of Performing Arts. And I got in, here in New York City, and got into ballet dance and got in, right. And thought, if I learned ballet, I can learn everything else. It I that idea, if you learn something classical, it can teach for everything else. And I was, yeah, at Alvin Ailey Dance School, Joffrey Ballet Dance School. And at the end of my senior concert, I had this opportunity to audition for the Alvin Ailey Dance Company. And I had an opportunity to go to college. And I also fell in love with another passion that my father had, which was science. And so I liked science in high school. And I found an overlap also between the arts and sciences, you know, both required creativity, hard work, discipline, you know, new discovery, both weren't boring to me. And the one decision I made at that senior dance concert was, you know, when talking to the Alvin Ailey recruiter and thinking about it, I have to make a decision. And I thought something my mother taught me because she was growing up in the 1960s cultural revolution, "Do something that has a positive impact on society." And I thought that I could do that better as a dancer than a scientist. So now jump, I get into college, undergraduate school, I major in molecular biology and mathematics. I decide I want to be a biologist, got into graduate school, wanted to study the brain at, you know, at the Rockefeller University. So I went from Hunter College to Rockefeller University. And so now I got to the brain and why did I choose the brain is because it controls dancing. [laughs] But there wasn't anybody studying dancing. And I wanted study the brain, something that it does that's really interesting and complex. And I thought, ah, language is what it does. You couldn't study that in mice. You couldn't study in non-human primates. But these birds do this wonderful thing that Fernando Nottebohm was studying at Rockefeller. And so that's what got me into the birds. And then jumping now, 15 years later, you know, yeah, that's right. Even after I'm into now having my own lab, studying vocal learning in these birds as a model for language and humans, it turns out that, you know, Ani Patel and, you know, others, have discovered that only vocal learning species can learn how to dance. - Is that right? - That's right, yes. - So I've seen these just scrolling through the files here in my mind. I think about, every once in a while someone will, I love parrots. - Yes. - So every once in a while, someone will send me one of these little Instagram or Twitter videos of a parrot doing what looks to me like dance, typically it's a cockatoo. - That's right. - Right. - That's right. - Even foot stomping to the sound and- - Famous one called Snowball out there, but there are many Snowballs out there. [laughs] - All the dancing birds are named Snowball? That's an interesting tactic. So only animals with language dance? - Yeah, vocal learning in particular, the ability to imitate sounds, yes. - Incredible. - Yes.

00:52:55 Motor Theory of Vocal Learning, Dance

And this now is bringing my life full circle, right. And so when that was discovered in 2009, at that same time in my lab at Duke, we had discovered that vocal learning brain pathways in songbirds, as well as in humans and in parrots, right, like Snowball, are embedded within circuits that control learning how to move. And that led us to a theory called the Brain Pathway or Motor Theory of Vocal Learning Origin where the brain pathways for vocal learning and speech evolved by a whole duplication of the surrounding motor circuits involving learning how to move. Now, how does that explain dance, right? Well, when Snowball, the cockatoos, are dancing, they're using the brain regions around their speech-like circuits to do this dancing behavior. And so what's going on there? What we hypothesize and now like to test is that when this, when speech evolved in humans and the equivalent behavior and parrots and songbirds, it required a very tight integration in the brain regions that can hear sound with the brain regions that control your muscles from moving your larynx and tongue and so forth for producing sound. And that tight auditory motor integration, we argue, then contaminated the surrounding brain regions. And that contamination of the surrounding brain regions now allows us humans, in particular, and parrots. to coordinate our muscle movements of the rest of the body with sound in the same way we do for speech sounds. - [Andrew] Well. - So we're speaking with our bodies when we dance. - Incredible. And I have to say that as poor as I am at speaking multiple languages, I'm even worse at dancing, so. - But I guarantee you're better than a monkey. - But not Snowball, the cockatoo? - No, maybe not Snowball. On YouTube, we have a video where there's some scientists dancing with Snowball and you'll see Snowballs doing better than some of the scientists. - Okay, well, as long as I'm not the worst of all scientists dancing. - I don't think so.

00:55:03 Music & Dance, Emotional Bonding, Genetic Predispositions

- There's always a neuroplasticity. May it save me someday. You said something incredible that I completely believe even though I have minimum to, let's just say minimum dancing ability. Okay, I can get by at a party or wedding without complete embarrassment, but I don't have any structured training. So the body clearly can communicate with movement. As a trained dancer and knowing other trained dancers, I always think of dance and bodily movement and communication through bodily movement as a form of wordlessness, like a state of wordlessness. In fact, the few times when I think that maybe I'm actually dancing modestly well for the context that I'm in, or I see other people dancing and they seem to just be very much in the movement, it's almost like a state of non-language, non-spoken language. - Hmm hmm. - And yet what you're telling me is that there's a direct bridge at some level between the movement of the body and language. So is there a language of the body that is distinct from the language of speech? And if so, or if not, how do those map onto one another? What does that Venn diagram look like? - Yeah, yeah. So, let me define first dance in this context of vocal learning species. This is the kind of dancing that we are specialized in doing and the vocal learning species are specialized in doing is synchronizing body movements of muscles to the rhythmic beats of music. And for some reason, we like doing that. We like synchronizing to sound and doing it together as a group of people. And that kind of communication amongst ourselves is more like the effective kind of communication I mentioned earlier, unlike the semantic kind. So we, humans, are using our voices more for the semantic, abstract communication, but we're using learned dance for the effective emotional bonding kind of communication. It doesn't mean we can't communicate semantic information in dance, and we do it, but it's not as popular. You know, like a ballet that, you know, in the Nutcracker, it is popular, you know, where they are communicating, you know, the Arabian guy comes out, which I was the Arabian guy in the ballet Nutcracker. That's how I remember. - Oh, yeah? - Yeah, for the Westchester Ballet Company, when I was a teenager. You know, we're trying to communicate meaning and our ballet dancing, it can go on with a whole story and so forth. But people don't interpret that as clearly as speech. You know, they're seeing the ballet with semantic communication, with a lot of emotional content, whereas you go out to a club, you know, yeah, you're not communicating, okay, how you're feeling today? Tell me about your day and so forth. You're trying to synchronize with other people in an effective way. And I think that's because, the dance brain circuit inherited the more ancient part of the speech circuit, which was for singing. - I always had the feeling that with certain forms of music, in particular opera, but any kind of music where there's some long notes sung that at some level, there was a literal resonance created between the singer and the listener. Or I think of like the deep voice of a Johnny Cash or where at some level, you can almost feel the voice in your own body. And in theory, that could be the vibration of the or the firing of the phrenic nerve controlling the diaphragm for all I know. Is there any evidence that there's a coordination between performer and audience at the level of mind and body? - I'm going to say, possibly, yes. And the reason why is because I just came back from a conference on the neurobiology of dance- - Clearly, I'm going to the wrong meetings. - Yeah, a colleague invited me. - You know, vision science sounds be so boring. - Yes, well, one of my colleagues, Tecumseh Fitch and Jonathan Fritz, they organized, well, a particular section on this conference in Virginia. And this is the first time I was in the room with so many neuroscientists studying the neurobiology of dance. It's a new field now, in the last five years. And there was one lab where they were putting EEG electrodes on the dancers, on two different dancers partnering with each other, as well as the audience, you know, seeing the dance and some, you know, argued, okay, if you're listening to the music as well, how are you responding 'cause you're asking a question about music and I'm giving you an answer about dance. And what they found is that, you know, the dancers, when they resonated with each other during the dance, or the audience listening to the dancers and the music, there's some resonance going on there that they've score as higher resonance. Their brain activity with these wireless EEG signals are showing something different. And so that's why I say possibly, yes. It needs more rigorous study and you know, this is some stuff they publish, but it's not prime time yet, but they're trying to figure this out. - Love it. So at least if I can't dance well, maybe I can hear and feel what it is to dance in a certain way. - Yes, that's right. And this will be, some people will think that they, even songs that they hear and they can almost sing to themselves in their own head and they know what they want it to sound like. And you know when it really sounds good, what it sounds like, but they can't get their voice to do it. - I'm raising, for those listening, I'm raising my hand. No musical ability. Others in my household have tremendous musical ability with instruments and with voice, but not me. - Yeah, well, and so this is one of my selfish goals of trying to find the genetics of why can some people who sing really well and some not. Is there some genetic predisposition to that? And then can I modify my own muscles of brain circuits to sing better? - You're still after the sing. I guess this is what happens when siblings vary in proficiency is that competitiveness amongst brothers and sisters never goes away. - I've been trying to be as good as my brother, Mark and Victor, you know, for my entire life. - Well, watch out, Mark and Victor, he's coming for you with neuroscience to back him. Earlier, you said that you discovered that you could dance. That caught my ear. It sounds like you didn't actually have to, I'm not suggesting you didn't work hard at it. But at the moment where you discovered it, it just sort of was a skill that you had, that up until that point, you didn't target a life in the world of dance, but the fact that you quote, unquote, "discovered that you could dance really well" and then went to this incredible school of dance and did well, tells me that perhaps there is an ability that was built up in childhood and or that perhaps we do all have different genetic leanings for different motor functions. - Yeah, well, for me, there could be, both explanations could be possible. For the first, yeah, I grew up in a family, listening to Motown songs, you know, dancing, you know, at parties and so forth, family parties and, you know, an African American family, basically. And so I grew up dancing from a young child, but this discovery, you know, maybe dancing even moreso, in terms of a talent, it could, the genetic component, if it really exists, I don't know. You know, with my 23andMe results, you know, it says I have the genetic substitutions that are associated with, you know, high intensity athletes and fast twitch muscles. And who knows. Maybe that could have something to do with me being able to synchronize my body to rhythmic sounds, maybe, maybe, better than some others. It turns out that my genetics also show that I have a genetic substitute that makes it hard for me to sing on pitch. And so that does correlate with my, you know, even though I can sing on this pitch, especially if I hear a piano or, you know, kind of playing it, but, you know, maybe that's why my siblings, you know, who didn't have that genetic predisposition in his 23andMe results, you know, it could go along with the genetic component, as well. - I'm imagining family gatherings with 23andMe data and intense arguments about it, innate and learned ability. - Yes. - Fun. Love to be an attendant. I'm not inviting myself to your Thanksgiving dinner by the way, but I suppose I am.

01:04:11 Facial Expressions & Language, Innate Expressions

- You're welcome to. - Thank you. I'll bring my 23andMe data. I'd love to chat a moment about facial expression because that's a form of motor pattern that, you know, I think for most people out there just think about smiling and frowning, but there are, of course, you know, thousands, if not millions of micro expressions and things of that sort, many of which are subconscious. And we are all familiar with the fact that when what somebody says doesn't match some specific feature of their facial expression that it can call, you know, that mismatch can cue our attention, especially among people that know each other very well. Like somebody will say, well, you said that, but your right eye twitched to the, you know, a little bit in a way that tells me that you didn't really mean that, these kinds of things. Or when, in the opposite example, when the emotionality and the content of our speech is matched to a facial expression, there's something that's just so wonderful about that, because it seems like everything's aligned. - [Erich] Yeah. - So how does the motor circuitry that controls facial expression map onto the brain circuits that control language, speech, and even bodily and hand movements? - Yeah, and you ask a great question because we both know some colleagues like Winrich Freiwald at Rockefeller University who study facial expression and the neurology behind it. And now we both share some students that we're co-mentoring. And talk about this same question that you brought up. And what I'm learning a lot is that non-human primates have a lot of diversity in their facial expression like we humans do. And what we know about the neurobiology of brain regions controlling those muscles of the face is that these non-human primates and some other species that don't learn how to imitate vocalizations, they have strong connections from the cortical regions to the motor neurons that control facial expressions, but absent connections or weak connections to the motor neurons that control the voice. So I think our diverse facial expression, even though it's more diverse in these non-human primates, there was already a preexisting diversity of communication, whether it's intentional or unconscious through facial expression in our ancestors. And on top of that, we humans now add the voice along with those facial expressions. - I see. And in terms of language learning when we're kids, I mean, children, fortunately are not told to fake their expressions or to smile when they say I'm happy. So at some point, everybody learns, for better or for worse, how to untangle these different components of hand movement, body posture, speech, and facial expression. - [Erich] Yes. - But in their best form, I would say, assuming that the best form is always, I guess there are instances where, you know, for safety reasons, one might need to fain some of these aspects of language. But in most cases, when those are aligned, it seems like that could reflect that all the different circuitries are operating in parallel, but that the ability to misalign these is also a powerful aspect to our maturation. I can think of theater, for instance, where deliberate disentangling of these areas is important. But also we know when an actor, when it feels real. - Yep. - And when it looks like, when bad acting is oftentimes when the facial expression or body posture just doesn't quite match what we're hearing. - [Erich] Yeah. - So are these skills that people, that learn and acquire according to adaptability and profession? Or do you think that all children and all adults eventually learn how to couple and uncouple these circuits a little bit? - Yeah, I think it's this similar argument I mentioned earlier about the innate and learned for the vocalizations. And by the way, when I say, we humans have facial expressions associated with our vocalizations in a different way than primates, non-human primates, it's the learned vocalizations I'm talking about. So there is a common view out there that facial expressions in non-human species like nonhuman primates, or you can have them in birds, too, are innate, all right. And so they're reflexive and controlled. I don't believe that. I think there's some learned component to it. And I think we have more learning component to it as well, but we also have an innate component. And so if you try to put your hands behind your back and hold your fist, or even just not, and try to speak and try to communicate, it's actually harder to do. You have to force yourself or put it by your side. This comes naturally. Facial expressions comes naturally because there's an innate component. And yes, you have to learn how to dissociate the two, communicate something angry with your hands or with your face, but, you know, politely with your voice. It's very hard to separate those two, because there is that innate component that brings them together. So it's like an email, too. You're emailing and someone says something by email, someone can interpret that angrily or gently,

01:09:35 Reading & Writing

and it becomes ambiguous. The facial expressions get rid of that ambiguity. - So glad you brought that up because my next question was, and is about written language. The first question I'll ask is when you write, either type or write things out by hand, do you hear the content of what you want to write in your head? Just, you personally. - Yes, I do. Yeah, and I know that I do, because I was trying to figure out a debate about this issue and trying to resolve the debate with my own self experimentation on me. - I asked that because, a quite well-known colleague of ours, Karl Deisseroth at Stanford, who's been on this podcast, you know, his optogenetics fame and psychiatry fame, et cetera. - Yeah, I know him. - Yeah, he sends his regards. - Okay. [laughs] - Told me that his practice for writing and for thinking involves a quite painful process of forcing himself to sit completely still and think in complete sentences, to force thinking in complete sentences. And when he told me that, I decided to try this exercise and it's quite difficult. First of all, it's difficult for the reason that you mentioned, which is that with many thoughts, I want to look around and I start to gesticulate with my hands, right? So there it is, again, the connection between language and hand movement, even if one isn't speaking. And the other part that's challenging is I realize that while we write in complete sentences, most of the time, we'll talk about how that's changing now. - Right. - In texting, et cetera. That we don't often think in complete sentences, and specifically in simple declarative sentences, that a lot of our thoughts would be, if they were written out onto a page would look pretty much like passive language that a good copy editor or a good editor would say, ugh, like we need to cross this out, make this simple and declarative. So what I'm getting at here is what is the process of going from a thought to language, to written word? And I also wanted to touch on handwritten versus typed, but thought to language, to written word. What's going on there? What do we know about the neural circuitry? And I was going to ask, why is it so hard? But now I want to ask why is this even possible? It seems like a very challenging neural computational problem. - Yeah, yeah. And coming from the linguistic world, and even just the regular neurobiology world, going back to something I said before about a separate language module in the brain. You know, there was this thought or hypothesis that this language module has all these complex algorithms to them. And they're signaling to the speech circuit, how to produce the sounds, the hand circuit, how to write them or gesture, the visual pathway on how to interpret them from reading and the auditory pathway for listening. I don't think that's the case, all right. And you know, that this thinking where there's this internal speech going on. What I think is going on is to explain what you're asking is about, that I'm going to take it from the perspective, reading something. You read something on a paper. The signal from the paper goes through your eyes. It goes to the back of your brain, to your visual cortical regions eventually. And then you now got to interpret that signal in your visual pathway of what you're reading. How are you going to do that in terms of speech? That visual signal then goes to your speech pathway in the motor cortex in front here, in Broca's area. And you silently speak what you read in your brain without moving your muscles. And sometimes actually, if you put electrodes, EEG, EMG electrodes on your laryngeal muscles, even on birds, you can do this, you'll see activity there while reading or trying to speak silently, even though no sound's coming out. And so your speech pathway is now speaking what you're reading. Now to finish it off, that signal is sent to your auditory pathways so you can hear what you're speaking in your own head. - That's incredible. - And this is why it's complicated because you're using like three different pathways, the visual, the speaking motor one, and the auditory to read. Oh, and then you got to write, right? Okay, here comes the fourth one. Now the hand areas next to your speech pathway has got to take that auditory signal or even the adjacent motor signals for speaking and translate it into a visual signal on paper. So, you're using at least four brain circuits, which includes the speech production and the speech perception pathways to write. - Incredible. And finally, explain to me why, so I was weaned teaching undergraduates, graduate students and medical students and I've observed that when I'm teaching, I have to stop speaking if I'm going to write something on the board. I just have to stop all speaking completely. - [Erich] Right. - It turns out this is an advantage to catch because it allows me to catch my voice. It allows me to slow down a bit, you know, breathe and inhale some oxygen and so on because I tend to speak quickly if I'm not writing something out. So there's a break in the circuitry for me, or at least they are distinct enough that I have to stop and then write something out.

01:15:13 Writing by Hand vs. Typing, Thoughts & Writing

- Yes, that does imply competing brain circuits for your conscious attention. - We have colleagues up at Columbia Med who are known, at least in our circles, for voice dictating their papers, not writing them out, but just speaking into a voice recorder. I've written papers that way. It doesn't feel quite as natural for me as writing things out. - Yeah. - But not because I can go quickly from thought to language to typing. I type reasonably fast. I can touch type now. I don't think I ever taught my, I think I taught myself. I never took a touch typing course. But it just sort of happened. Now, I think, my motor system seems to know where the keys are with enough accuracy, that it works. This is remarkable to me that any of us can do this. But when it comes to writing, what I've found is that if my rate of thought and my rate of writing are aligned nicely, things go well. However, if I'm thinking much faster than I can write, that's a problem. And certainly, if I'm thinking more slowly than I want to write, that's also a problem. And the solution for me has been to write with a pen. I'm in love with these. And I have no relationship to the company, at least not now, although if they want to come, you know, if they want to work with us, I love these Pilot V5, V7's because not necessarily because of the ink or the feel, although I like that as well. But because of the rate that it allows me to write, they write very well slowly, and they write very well quickly. And so I have this theory, supported only by my own anecdata, no peer reviewed study, that writing by hand is fundamentally different than typing out information. Is there any evidence that this motor pathway for writing is better or somehow different than the motor pathway for typing? - Yeah, that's interesting. And I don't know of any studies. I have my own personal experience as well, but trying to put this into the context, if I had to, you know, design an experiment to test the hypothesis here that, you know, to explain your experience and mine, is that writing by hand, I would argue, requires a different set of less skills with the fingers than typing. So you have to coordinate your fingers more in opposite directions and so forth with typing, but also writing by hand requires more arm movement. And so therefore, I would argue that the difficulty there could be in the types of muscles and the fine motor control you need of those muscles along with speaking in your brain at the same time. - So basically, I'm a course, I'm a brute. So it makes sense that I would have, a more primitive writing device would work. - That's right, yes. But, let me answer this in terms of my own personal experience, right. What I find is I can write something faster by hand for a short period of time, compared to typing. And that is because I think I run out of the energy in my arm movements faster than I run out of muscle energy in my finger movements. And I think it takes longer time for us to write words with our fingers, because, and in terms of the speech. So I think your writing, whether it's by hand or typing and your speech, they only will align very well if you can type as fast as you can speak or write as fast as you can speak in your head. - I love it. So what you've done, if I understand correctly, is created a bridge between thought and writing, and that bridge is speech. - That bridge is speech, that's right. That's right. When you're writing something out, you're speaking it to yourself. And if you're speaking faster than you can type, you've got a problem. - Interesting. I do a number of podcast episodes that are not with guests, but solo episodes. And as listeners know, these are very long episodes, often two or more hours. And we joke around the podcast studio that I will get locked into a mode of speech where some of it is more collaborative and anecdotal and then I'll punch out simple declarative sentences. I find it very hard to switch from one module to the next. The thing that I have done in order to make that transition more fluid and prep for those podcast episodes is actually to read the lyrics of songs and to sing them in my head as a way of warming up my vocal chords. But luckily for those around me, when I do that, I'm not actually singing out loud. And so this, what you're telling me supports this idea that even when we are imagining singing or writing in our mind, we are exercising our vocal chords. - You're actually getting little low potentials of electrical currents reaching your muscles there, which also means you're exercising your speech brain circuits too, without actually, you know, going with the full-blown activity in the muscles. - Incredible. - Yeah. And this idea of singing helps you as well. Even with Parkinson's patients and so forth, when they want to say something, singing or listening to music helps them move better. And the idea there is that the brain circuits for singing, or let's say the function of the brain circuits for speech being used for singing first is the more ancestral trait. And that's why it's easier to do things with singing

01:20:58 Stutter, Neurogenetics, Overcome Stutter, Conversations

sometimes than it is with speaking. - I love it. Stutter is a particularly interesting case and one that every once in a while, I'll get questions about this from our audience. Stutter is complicated in a number of ways, but culturally, and my understanding from these emails that I receive is that stutter can often cause people to hide and speak less because it can be embarrassing. And we are often not patient with stutter. We also have the assumption that if somebody's stuttering, that they're thinking is slow, but it turns out there are many examples, historically of people who could not speak well, but who were brilliant thinkers. I don't know how well they could write, but they found other modes of communication. I realize that you're not a speech pathologist or therapist, but what is the current neurobiological understanding of stutter and, or what's being developed in terms of treatments for stutter? - Yeah, so we actually accidentally came across stuttering in songbirds. And we've published several papers on this to try to figure out the neurobiological basis. The first study we had was a brain area called the basal ganglio, or the striatum part of the basal ganglia involved in coordinating movements, learning how to make movements, when it was damaged in a speech-like pathway in these birds, what we found is that they started to stutter as the brain region recovered. And unlike humans, they actually recovered after three or four months. And why is that the case? Because bird brains undergoes new neurogenesis in a way that human or mammal brains don't. And it was the new neurons that were coming in into the circuit, but not quite, you know, with the right proper activity was resulting in this stuttering, in these birds. And after it was repaired, not exactly the old song came back after the repair, but still it recovered a lot better. And it's now known, they call this neurogenic stuttering in humans, damage to the basal ganglia or some type of disruption to the basal ganglia at a young age, also causes stuttering in humans. And even those who are born with stuttering, it's often the basal ganglia that's disrupted than some other brain circuit and we think the speech part of the basal ganglia. - Can adults who maintain a stutter from childhood repair that stutter? - They can repair it with therapy, with learning how to speak slower, learning how to tap out a rhythm. And yeah, I'm not a speech pathologist, but I started reading this literature and talking to others, that you know, colleagues who actually study stuttering. So yes, there are ways to overcome the stuttering through, you know, behavioral therapy. And I think all of the tools out there have something to do with sensory motor integration, controlling what you hear with what you output in a thoughtful controlled way helps reduce the stuttering. - There are a couple examples from real life that I want to touch on, and one is somewhat facetious, but now I realize, is a serious neurobiological issue, serious meaning I think interesting. Which is that every once in a while, I will have a conversation with somebody who says the last word of the sentence along with me. And it seems annoying in some instances, but I'm guessing this is just a breakthrough of the motor pattern that they're hearing what I'm saying very well. So I'm going to interpret this kindly and think they're hearing what I'm saying. They're literally hearing it in their mind and they're getting that low-level electrical activity to their throat. And they're just joining me in the enunciation of what I'm saying, probably without realizing it. Can we assume that that might be the case? - Well, I wouldn't be surprised so that, you know, the motor theory of speech perception where this idea originally came, what you hear is going through your speech circuit and then also activating those muscles slightly. So yes, so one might argue, okay, is that speech circuit now interpreting what that person is speaking? Now, you're listening to me and is going to finish it off because it's already going through their brain and they can predict it? That would be one theory. And I don't think the verdict out there is known, but that's one. The other is synchronizing turn-taking in the conversation where you're acknowledging that we understand each other by finishing off what I say. And it's almost like a social bonding kind of thing. The other could be, I want the person to shut up so I can speak as well and take that turn. And each pair of people have a rhythm to their conversation. And if you have somebody who's over talkative versus under talkative of vice versa, that rhythm can be lost in them finishing ideas and going back and forth. But I think having something to do with turn-taking, as well, makes a lot of sense. - I have a colleague at Stanford who says that interruption is a sign of interest. [Erich laughs] I'm not sure that everyone agrees. I think it's highly contextual. - [Erich] Yes. - But there is this form of a verbal nod of saying, hmm hmm or things of that sort. And they're many of these. And I'm often told by my audience, you know, that I interrupt my guests and things of that sort. Oftentimes, I'll just get caught in the natural flow of the conversation, but. - Right. Well, I think we've had pretty good turn-taking here, I hope. - So far so good. - I feel that way. - I'm glad you feel that way, because especially in the context of a discussion

01:26:58 Modern Language Evolution: Texting, Social Media & the Future

about language. - Yes. - It seems important. Texting is a very, very interesting evolution of language because what you've told us is that we have a thought, it's translated into language. It might not be complete sentences, but texting, I have to imagine this is the first time in human evolution where we've written with our thumbs. So I don't know, it seems more primitive to me than typing with fingers or writing with hands, but hey, who am I to judge the evolution of our species in one direction or the other? But the shorthand grammatically, often grammatically deficient incomplete sentence form of texting is an incredible thing to see. Early in relationships, romantic relationships, people will often evaluate the others text and their ability to use proper grammar and spelling, et cetera. This often quickly degrades. And there's an acceptance that we're just trying to communicate through shorthand, almost military like shorthand, but with internally consistent between people, but there's no general consensus of what things mean, but, you know, WTFs and like, and OMGs and all sorts of things. - [Erich] Right. - I wonder sometimes whether or not we are getting less proficient at speech because we are not required to write and think in complete sentences. - Hmm hmm. - I'm not being judgemental here. I see this in my colleagues. I see this in myself. This is not a judgment of the younger generation. I also know that slang has existed for decades, if not hundreds of years. But I also know that I don't speak the same way that I did when I was a teenager, because I've suppressed a lot of that slang, not because it's inappropriate or offensive, although some of it was, frankly, but because it's out of context. So what do you think's happening to language? Are we getting better at speaking, worse at speaking? And what do you think the role of things like texting and tweeting and shorthand communication, hashtagging, what's that doing to the way that our brains work? - Yeah, I think that, well, one, in terms of, you know, measuring your level of sophistication and intelligence when you say OMG, right. I think that also could be a cultural thing that, ah, you belong to the next generation. If you're an, you know, or you're being cool, if you're an older person, you know, using OMG and other things that the, you know, younger generation would use. But if I really think about it clearly, texting actually has allowed for more rapid communication amongst people. I think, without the invention of the phone before then, or, you know, texting back and forth, you had to wait days for a letter to show up. You couldn't call somebody on the phone and talk as well, you know? And so this rapid communication in terms of the rapid communication of writing in this case. So I think actually, it's more like a use it or lose it kind of a thing with the brain. The more you use a particular brain region or circuit, the more enhanced. It's like a muscle. The more you exercise it, the more healthier it is, the bigger it becomes and the more space it takes and the more you lose something else. So I think texting is not decreasing the speech prowess, or the intellectual prowess of speech. It's converting it and using it a lot in a different way, in a way that may not be as rich in regular writing, because you can only communicate so much nuance in short-term writing, but whatever is being done, you got people texting hours and hours and hours on the phone. So whatever, your thumb circuit is going to get pretty big, actually. [laughs] - I do wonder whether, you know, many people have lost their jobs based on tweets. - [Erich] Hmm hmm. - The short latency between thought and action and distribution of one's thoughts is incredible. - Yes. - And I'm not just talking about people who apparently would have poor prefrontal top-down control. This is geek speak by the way, for people that lack impulse control. But high-level academics, I'm not going to point fingers at anyone. But examples of where you see these tweets and you go, what were they thinking? - Yep. - So presumably, there's an optimal strategy between the thought speech motor pathway, especially when the motor pathway engages communication with hundreds of thousands of people and retweets in particular and the cut and paste function and the screenshot function are often the reason why speech propagates. - [Erich] Yep. - So to me, it's a little eerie that, just that the neural circuitry can do this and that we are catching up a little bit more slowly to the technology, and you've got these casualties of that mismatch. - I think that's a good adjective used, the casualties, you know, of what's going on, because yes, it is the case with texting, what you're really losing there is less so the ability to write, but more the ability to interpret what is being written. And you can over or under interpret something that somebody means. On the flip side of that, you know, if somebody's writing something very quick, they could be writing instinctually, more instinctually, their true meaning, and they don't have time to modify and color code what they're trying to say. And that's what they really feel and as opposed to saying it in a more nuanced way. So I think both sides of that casualty are present. And that's a downturn, you know, unintended negative consequence of short-term, I mean, short-word communications. - Yeah, I agree that this whole phenomenon could be netting people that normally would only say these things out loud once inside the door of their own home. - Right. - Or not at all. - [Erich] Right. - It's an interesting time that we're in. These are these speech and language and motor patterns. - So part of the human evolution for language, I think this is all part of our evolution. - That's right. - Yeah. - So for those of you thinking terrible thoughts, please put them in the world and be a casualty. And for those of you that are not, please be very careful with how proficient your thought to language to motor action goes. - [Erich] Yes. [laughs] - Maybe the technology companies should install some buffers, some AI-based buffers. - Right, that's taking some EEG signals from your brain while you're texting to say, okay, this is not a great thought, slow down. - Right, or this doesn't reflect your best state. That brings me to what was going to be the next question anyway, which is we are quickly moving toward a time where there will be an even faster transition from thought to speech, to motor output, and maybe won't require motor output. What I'm referring to here is some of the incredible work of our colleagues, Eddie Chang at UCSF and others who are taking paralyzed human beings and learning to translate the electrical signals of neurons in various areas, including speech and language areas, to computer screens that type out what these people are thinking. In other words, paralyzed people can put their thoughts into writing. That's a pretty extreme and wonderful example of recovery of function. - Hmm hmm. - That is sure to continue to evolve. But I think we are headed toward a time, not too long from now where my thoughts can be translated into words on a page if I allow that to happen. - Yeah so, and Eddie Chang's work, which I admire quite a bit and cite in my papers, I think he's really one of those at the leading edge of trying to understand within humans, the neurobiology of speech. And he may not say it directly, but you know, I talked to him about this. It supports this idea that the speech circuit and the separate language module, I don't really think that there's a separation there. So with that knowledge, yes, and putting electrodes into human brain and then translating those electrical signals to speech currents. Yeah, we can start to tell what is that person thinking? Why, because we often think in terms of speech. And without saying words. And that's a scary thought. And now imagine if you can now translate those into a signal that transmits something wirelessly and someone from some distant part of the planet is hearing your speech from a wireless signal without you speaking. So probably that won't be done in an ethical way, who knows, you know? But I mean, the ethics of doing that probably, you know, might not happen, but who knows? We have these songbirds, you know. If we apply the same technique to them, we can start to hear what they're singing in their dreams or whatever, even though they don't produce sound so we can find out by testing on them.

01:36:26 Movement: The Link to Cognitive Growth

- It's coming. - Yes. - One way or another, it's coming. For those listening who are interested in getting better at speaking and understanding languages, are there any tools that you recommend? And here again, I realize you're not a speech therapist, but here I'm not thinking about ameliorating any kind of speech deficiency. I'm thinking, for instance, do you recommend that people read different types of writing? Would you recommend that people learn how to dance in order to become better at expressing themselves verbally? You know, and feel free to have some degrees of freedom in this answer. These are obviously not peer-reviewed studies that we're referring to, although there may be, but I'm struck by the number of things that you do exceedingly well, and I can't help but ask, well, the singing, which I realize it may, your brother didn't pay me to say this, may not be quite as good as your brothers yet, but is getting, you'll surpass him, I'm guessing at some point. ♪ Getting there ♪ - Getting there. [both laughing] Exactly, there you go. You know, should kids learn how to dance and read hard books and simple books? What do you recommend? Should adults learn how to do that? Everyone wants to know how to keep their brain working better, so to speak. But also I think people want to be able to speak well and people want to be able to understand well. - Yeah, so what I've discovered personally, right, is that, so when I switched from pursuing a career in science from a career in dance, I thought one day I would stop dancing, but I haven't because I find it fulfilling for me, you know, just as a life experience. So ever since I started college, you know, my late teens and early twenties, I kept dancing even till this day. And there've been periods of time, like during the pandemic where I slowed down on dancing and so forth. And when you do that, you realize, okay, there are parts of your body where your muscle tone decreases a little bit and somewhat, or you could start to gain weight. I somehow don't gain weight that easily. And I think it's related to my dance, if that's meaningful to your audience. But what I found is, you know, in science, we like to think of a separation between movement and action and cognition. And there is a separation for you between perception and production, cognition being perception, production being moving, right. But if the speech pathways is next to the movement pathways, what I discover is by dancing, it is helping me think. It is helping keeping my brain fresh. It's not just moving my muscles, I'm moving or using the circuitry in my brain to control a whole big body. You need a lot of brain tissue to do that. And so I argue, if you want to stay cognitively intact into your old age, you better be moving and you better be doing it consistently, whether it's dancing, walking, running, and also practicing speech, oratory speech and so forth or singing, is controlling the brain circuits that are moving your facial musculature. And it's going to keep your cognitive circuits also in tune. And I'm convinced of that from my own personal experience. - Yeah, for me, long, slow runs are a wonderful way to kind of loosen the joints for long podcasts, especially the solo podcast, which can take many hours to record. And without those long slow runs, at least the day before, or even the morning of, I don't think I could do it, at least not as well. - All right, well, you're experiencing something similar. So that's an N of two. - Yeah, N of two. I'm tempted to learn how to dance because there are a lot of reasons to learn how to dance.

01:40:21 Comparative Genomics, Earth Biogenome Project, Genome Ark, Conservation

- [Erich] Yes. - And people can use their imagination. I definitely want to get the opportunity to talk about some of the newer work that you're into right now about genomes of animals. As you perhaps can tell from my quite authentic facial expressions, I adore the animal kingdom. I just find it amazing. And it's the reason I went into neurobiology, in part. So many animals, so many different patterns of movement, so many body plans, so many specializations, what is the value of learning the genomes of all these animals? You know, I can think of conservation-based, you know, schemes of trying to preserve these precious critters, but what are you doing with the genomes of these animals? What do you want to understand about their brain circuits? And how does this relate to some of the discussion we've have been having up until now? - Yeah, I've gotten very heavily involved in genomes, you know, not just to get at an individual gene involved in the trade of interest, like spoken language, but I realize that, you know, nature has done natural experiments for us with all these species out there with these various traits and the one that I'm studying, like vocal learning, has evolved multiple times among the animal kingdom, even if it's rare, it's multiple times. And the similar genetic changes occurred in those species. But to find out what those genetic changes that are associated with the trait of interests and not some other trait like flying in birds, as opposed to singing, you have to do what's called comparative genomics, even in the context of studying the brain. And you need their genomes to compare the genomes and do like a GWA, a genome-wide association study, not just within a species like humans, but across species. And so you need good genomes to do that. Plus, I've discovered I'm also interested in evolution and origins. How did these species come about a similar trait in last, you know, 300 million years or 60 million years, depending who you're talking about. And you need a good phylogenetic tree to do that, and to get a good phylogenetic tree, you also need their genomes. And so, because of this, I got involved in large scale consortiums to produce genomes of many different species, including my vocal learners and their closest relatives that I'm fans of. But I couldn't convince the funding agencies to gimme the money to do that just for my own project. But when you get a whole bunch of people together who want to study various traits, you know, heart disease, or loss and gain in flight and so forth, suddenly we all need lots of genomes to do this. And so now that got me into a project to lead something called the Vertebrate Genomes Project to eventually sequence all 70,000 species on the planet. And Earth BioGenome Project, all eukaryotic species, all two million of them. And to no longer be in a situation where I wish I had this genome. Now we have the genetic code of all life on the planet, create a database of all their traits and find the genetic association with everything out there that makes a difference from one species to another. One more piece of the equation to add to this story is what I didn't realize as a neuroscientist were that these genomes are not only incomplete, but have lots of errors in them, false gene duplications, where mother and father chromosomes were so different from each other, that the genome algorithm, assembly algorithms treated them as two different genes in this part of the chromosome. So there are a lot of these false duplicated genes that people thought were real, but were not or missing parts of the genome because the enzymes used to sequence the DNA couldn't get through this regulatory region that folded up on itself and made it hard to sequence. And so I ended up in these consortiums pulling in the genome sequencing companies, developing the technology to work with us to improve it further and the computer science guys who then take that data and that technology, and try to make the complete genomes and make the algorithms better to produce what we now just did recently led by an effort by Adam Phillippy is the first human Telomere-to-Telomere Genome with no errors, all complete, no missing sequence. And now we're trying to do the same thing with vertebrates and other species. Actually, we improved that before we got to the, what we call telomere-to-telomere, from one end of the chromosome to another. And what we're discovering is in this dark matter of the genome that was missing before, turns out to be some regulatory regions that are specialized in vocal learning species and we think are involved in developing speech circuits. - Incredible. Well, so much to learn. And we're going to learn from this information. Early on in these genome projects and connectome projects, I confess I was a little bit cynical. This would be about 10, 15 years ago. I thought, okay, necessary, but not sufficient for anything. We need it, but it's not clear what's going to happen, but you just gave a very clear example of what we stand to learn from this kind of information. And I know from the conservation side, there's a huge interest in this because even though we would prefer to keep all these species alive rather than clone them, these sorts of projects do offer the possibility of potentially recreating species that were lost. - [Erich] Right. - Due to our own ignorance or missteps, or what have you. - Yes, and along those lines, because, you know, we got involved in genomics, some of the first species that we start working on are critically endangered species. And I'm doing that not only for, you know, perspectives to understand their brains and the genes involved in their brain function, but I feel like it's a moral duty. So the fact that now I become more involved in genome biology and have helped develop these tools for more complete genomes, let's capture their genetic code now, before they're gone. And could we use that information to resurrect the species at some future time, if not in my lifetime, in some time in the future and generations ahead of us. And so, in anticipation of that, we create a database, we call the GenomeArk and no pun intended like Noah's Ark, meant to store the genetic code as complete genome assemblies as possible for all species on the planet to be used for basic science, but also some point in the future. And because of that, funding agencies or private foundations that are interested in conservation have been reaching out to me now, a neuroscientist, to help them out in producing high quality genome data of endangered species that they can use, like Revive & Restore, who want to resurrect the passenger pigeon or Colossal, who wants to resurrect the wooly mammoth. And so we're producing high quality genomes for these groups, for the conservation projects. - What a terrific and important initiative. And I think for those listening today, they now certainly understand the value of deeply understanding the brain structures and genomes of different species. Because I confess, even though I knew a bit of the songbird literature, and I certainly understand that humans have speech and language, I had no idea that there was so much convergence of function, structure and genomes. And to me, you know, I feel a lot more like an ape than I do a songbird. - Right. - And yet here we are with the understanding that there's a lot more similarity

01:48:24 Evolution of Skin & Fur Color

between songbirds and humans than I certainly ever thought before. - Yeah, something very close to home for us humans, I can give you an example of is evolution of skin color. And skin color, we use it unfortunately, for racism and so forth. We use it also for good things to let in more light or let out less light depending on the part of the planet, you know, our population evolved in. And most people think dark-skinned people all evolved from the same dark-skinned person and light-skinned people all evolved from the same light-skinned person, but that's not the case. Dark skin and light skin amongst humans has evolved independently multiple times, like in, you know, the Pacific islands versus Africa. And it's just depending on the angle of light hitting the Earth as to whether you need more protection from the sun or less protection, that's also associated with Vitamin D synthesis in the skin. And so, and each time, where darker or lighter skin evolved independently, it hit the same gene, you know, the mela [finger snaps]. - Melanin. - Melanin receptors. That's right, yes, yeah. Genes that are involved in melanin in formation. And so those genes evolve some of the same mutations, even in different species. It's not just humans. In equatorial regions, they are darker-skinned animals than going away from the equator. - Oh, right, I think of Arctic foxes and things of that sort. - Yep, that's right. That's right, polar bears, you know, and so some of the same genes are used in evolutionary perspective to evolve in a similar way within and across species. - Incredible. - Yeah. And that's same thing happening in the brain too. Language is no exception. - Well, I have to say, as somebody who is a, you know, career neuroscientist, but as I mentioned several times now, who also adores the animal kingdom, but is also obsessed with speech and language, at a distance not as a practitioner of music and dance, this has been an incredible conversation and opportunity for me to learn. And I know I speak for a tremendous number of people and I just really want to say, thank you for joining us today. You are incredibly busy. It's clear from your description of your science and your knowledge base, that you are involved in a huge number of things, very busy, so thank you for taking the time to speak to all of us. Thank you for the work that you're doing, both on speech and language, but also this important work on genomes and conservation of endangered species and far more. And I have to say, if you would agree to come back and speak to us again sometime, I'm certain that if we were to sit down even six months or a year from now, there's going to be a lot more to come. - Yeah, we have some things cooking and thank you for inviting me here to get the word out to the community of what's going on in the science world. - Well, we're honored and very grateful to you, Erich.

01:51:22 Dr. Erich Jarvis, Zero-Cost Support, YouTube Feedback, Spotify & Apple Reviews, Momentous Supplements, AG1 (Athletic Greens), Instagram, Twitter, Neural Network Newsletter, Huberman Lab Clips

Thank you. - You're welcome. - Thank you for joining me today for my discussion with

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