Tobias Hauser

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SPEAKERS

Caswell Barry, Steve Flemming, Tobias Hauser

Caswell Barry 00:00
Hello, and welcome to brain stories. I'm Caswell Barry. I'm here with my co host Stephen Fleming.

Steve Flemming 00:07
On brain stories, we aim to provide a behind the scenes profile of the latest and greatest work in neuroscience, highlighting the stories and the scientists who are making this field tick.

Caswell Barry 00:17
We don't just to ask about science, we asked about how the scientists got to where they are today, and where they think their field is going in the future.

Steve Flemming 00:26
And today, it's a real pleasure to be joined by Tobias Hauser him who is a principal research fellow at UCL and he leads the developmental computational psychiatry group at the Max Planck Centre for computational psychiatry and ageing research. So Tobias did his PhD in child and adolescent psychiatry at University of Zurich, and then came to UCL where he started off as a postdoc in Radiosondes group. And then he got his own prestigious welcome Henry Dale fellowship to start up his own lab focused on looking at how psychiatric disorders emerge in development in childhood and adolescence. And, as we'll hear, Tobias is interested in understanding the computational processes underlying a range of disorders, particularly obsessive compulsive disorder, and attention deficit hyperactivity disorder. So welcome, Tobias. Thanks very much for coming on the podcast.

01:32
Thanks so much for inviting me.

Steve Flemming 01:35

So what we'd like to do to kick off is really just get our audience oriented to what you're currently working on. So if you could just give us a brief summary of what your research focuses on? And what are the key questions you're working on at the moment?

Tobias Hauser 01:52
Yes, I mean, you already very nicely introduced the big strokes. Are we interested? We are really interested in understanding why so many mental illnesses emerge during childhood and less than and adolescence. So what is it that makes it in particularly adolescence such a vulnerable period for mental health? And will we try to understand that trying to study the brain, and how the brain develops and how cognition develops, using both neuroimaging methods as well as computation models? And the big questions that really erase from that is trying to understand what is happening in the brain during childhood and adolescence, what what changes until we become adults? What are the trajectories of brain growth, so to say, and how brain function changes and specialises? And how does that maybe go awry and lead to mental illness such as OCD, as you mentioned, or ADHD? So how the hell are these two tied together? And if we understand that, can we use that to, for example, predict mental illness? So can we find determines that predict whether someone is going to develop, let's say in OCD or not? And if we do so, can we then also create interventions which might actually act before the illness actually arises? Can we like so preventative treatments, that that is kind of the long goal to hopefully detect it early and prevent these disorders from emerging.

Steve Flemming 03:39
And, and running through your research and the title of the field computational psychiatry is this word computation, which I think is an unusual and exciting approach, compared to say, a lot of work that has been done in the past in psychiatry, and I'm wondering whether you could just give us a brief definition on what you mean by computation there or computational model?

04:04
Yeah, that's a very good question. Competition now pops up almost everywhere. And, and the field of computational psychiatry is actually still relatively young, I think it started about 10 years ago. And what it actually means is that we use mathematical models. So we describe the computations. And these mathematical models try to imitate what the brain is doing. So we know that the brain is this extremely elaborate information processing machines. And we understand some of the principles of these processes. And we are describing them mathematically. And by having these mathematical models we can then mess these models and see how do we have to tweak it. How do we have to adapt it so that it matches what an adolescent is playing in a game? And by doing that we can actually understand the likely processes that are taking place in the brain.

Caswell Barry 05:07
How I'm curious, how successful is this approach been? I mean, in my, I guess what I'm notionally doing is comparing to my own field where models are very often sort of post hoc, explanatory rather than having any direct predictive power. I know people would say differently, but that's the cynics view. Have these models been sort of successful in predicting new mechanisms of disease or predicting how disease might appear or giving you new avenues into tackling them or predicting them earlier?

05:37
Good question. So obviously, they these models, and probably the start of the field was rather serendipitous where people have had these recordings of dopamine neurons that looked funny. And then some other people like Reed Montague, and Peter, Diane, were working in artificial intelligence, and had models, mainly to train artificial agents. And and came across these kinds of data and realised, oh, that matches up pretty well. So that was a total serendipitous discovery. And that has been extremely. And this discovery has led to a huge bulk of work and lots of new insights. And I think, even though this was kind of post hoc, in a way, I think it was so like, the literature that spilled on that has shown how potent this idea was, because we've now seen very similar signals all across the brain, in different domains, in different functions, which, and and it's like, constantly evolving, we're refining these computational models and deep understanding. And I think that that really has shown that yes, we can predict at least behaviour and brain activation. And similarly in some of the work that I have done, where we knew that these these prediction errors, or these mathematical signals, which tell you how much my how much how well I was predicting the future, essentially, they were usually just set in the domain of reward. So if you get something nice, like a food pellet, or some money if you're a human, and then some of the work that we've been doing is that we looked at the same thing in the domain of effort. So how much work? How much effort do you have to put in and we also hypothesised that it's following the similar principles. And so we have this idea that it's processed in maybe similar but slightly distinct pathways, and we then didn't memorise study of a few years back. And indeed, we saw that these prediction errors not only exist for rewards, but also for efforts so that humans adjust not only their expectations about how much money or points they get, but also they adjust how much effort they have to put in to receive these points. And we saw that these were processed in a separate pathway. So more in MS a cortical pathway including the dorsal medial prefrontal cortex, whereas these previously known rewarding us for mainly processed in the ventral striatum, then we had like very concrete hypotheses, which really turned out so that there was a huge predictive power. Now, how good are these models in predicting mental health? is a completely different question. And I think the answer to that we don't yet have. I think that's, that's where we are working at. So we know, the state of the few this usually is more or less that we know that there are links. So we know that certain populations that are suffering from depression, or schizophrenia, or OCD, seem to have changes in these computational mechanisms. But when we look at the predictive power, so can we predict whether someone is ill or not just by using these methods? We are not yet that great. And there are many caveats why this is, and I think we are not asking the right questions. And that's probably why we're not that successful yet.

Steve Flemming 09:30
So it's, it's interesting that you introduce your answer with the, you know, the classic example from reinforcement. And it was just seemed to be just an amazing example of the tight linkage between algorithm drawing from work in learning theory and then how the brain works. But I'm just wondering whether, in your opinion, do you think RL reinforcement learning models have been a bit of a blessing and a curse for computational psychiatry because it's been so successful So then there's a tendency to kind of think about reinforcement learning process and how they map onto mental health. And maybe there's other types of computation that we should also be thinking about.

10:12

Yes, definitely. I mean, it has really over the last, I think when I started out, I did my start in my PhD, and I thought it would be a cool idea to use these mathematical models. In mental health. Before the word competition, psychiatry was even a term. And obviously, the last 10 years, it really has seen like an explosion of people using it. And when I do my PC wasn't clear that RL is going to be the dominant one, there are lots of alternative good models, which are equally valid. And I think we are not actually very good at distinguishing them properly. I think it's the rare there's a risk, where you just follow the herd, and that your new hammer is RL. And every illness is like is your nail and you can explain everything. And that is often the case is that's likewise the case with other computational approaches. And I think that's more or less just a sign of, of scientists believing that their hammer is is the ultimate hammer. So if you speak to visual scientists, maybe they think it's all individual cortex. Or if you speak to cats, well, it might be all cells.

11:40
So I think, you know, it's a very good way of describing certain processes. But it also has its limitations. And we can only get so far, but I think the field as I see it is flexible enough that that I feel like that they are able to Yeah, it's not so dogmatic. So so the field is open to new suggestions and further developments and expanding it in paths, you know, like beyond just behaviour, also to self reports. And we've seen the last couple of years very good results coming out. That linked self reports to like this more classic reinforcement learning.

Caswell Barry 12:24
And I guess maybe moving towards some of your own research now, sort of So how well does things like obsessive compulsive disorder fit into like, this framework that's been established? You know, like the we've just talked about the sort of successes of RL and its length, you know, and the biological implementation they're off. Is that is that a broad enough church that you can sort of that these other diseases can sort of easily fit in there? Or what is you know, how, I guess what I'm really asking you is, how do you approach studying obsessive compulsive disorder? And maybe I should ask you to say what it is because I guess OCD is possibly one of those misused terms around

13:06
Yes, it is really has a difficult stamp thing, because it is used very much in the common language, but it was modelled mostly misused. People often say, Oh, I'm a bit OCD when they're just referring to being slightly tidy. Which is exactly it's not at all what OCD is. OCD is short for obsessive compulsive disorder. And it is a very common and debilitating disorder. But it is completely neglected, both clinically as well as scientifically. So the main symptoms are as the name says, obsessions and compulsions. So obsessions are intrusive thoughts or images, which caused a lot of distress. So that could be that you think, oh, did I accidentally put some bleach into the fruit that I prepared for my children? And are my children going to die from it? Or it could be that if then if I don't do something, then there's some horrendous accident happening. Or domain house could burn down. So it's very varied. But these thoughts, they come into your mind that they stick there, and they're really really distressing. And so to get rid of this distress, many patients with OCD use compulsions, which are repetitive behaviours, or mental acts. So that could be from what is usually known, like the hand washing, but it's also often checking or mental rituals, like counting to a certain number and so on. And they don't just do that once or twice. It's not like if you wash your hands thoroughly, that's not OCD. They do it for hours and hours

and hours every day. And it's really, really impairing. So Are many patients that we're working with, they struggle to keep up their job because of their OCD. OCD really takes a life of its own and takes over their life and kind of many patients that we're working with. Talk about, like it's sitting on their shoulder and dominating what they're doing. So it's really impairing. And there's a lot of work that we have to do to D stigmatise OCD, and actually make it make the public more aware, more aware of what it is, and we're working, we have a couple of public engagement project on that front. Now, it's very common, it affects 3% of the population about that's one in 33 people and it's very hidden, because those affected by OCD, they are usually aware of it. And they are aware that this is all that they can't quite rationally explain why it happens to them. So they often keep it on the list, they don't really talk and share it with your, with their friends and family. And so that's why we are not very aware of it. And I think there needs to be a change as well that we understand how common it is. But even though it affects 3%, which is like much more common than, let's say, autism, or schizophrenia, if you look at the research funding, it's it's a fraction of that. So you can compare how much money we probably spent, for example, spending in the UK, and it's much, much less than for autism, or schizophrenia. And that shows just that we are still very early days in OCD research. And that's how I come to your original question, which is, how do you study as the and one of the challenges with OCD is really, that we know, we still know fairly little, I think we've made a lot of progress in the, let's say, bigger or more researched disorders like depression, anxiety, maybe even schizophrenia, whereas OCD is only very few people in the world that actually study OCD. And so we are still probably a bit behind from what other disorders have. And so there are a few competing ideas of what is driving our city. And that comes because of the heterogeneity of those, the when I gave these examples in the beginning, you can see they're very varied, you know, it goes from hygiene to hand with hand washing to like repetitive checking. And so each of those, this very heterogeneous symptom picture leads to different speculations about what could be the cause of it. And so there are different a range of different ideas, what is driving us the one is that the that OCD is very much driven by doubt that they have like that they need to be more certain about things until they're certain. And that's why they go back and check again. That's why they do stuff repeatedly. And we have a line of research where we look at how people gather information and how much information they need. And until they make a decision. There is another hypotheses that this is all just habits that habitual system takes over. And that we are that those affected by OCD are not actually that aware when they are conducting their compulsions. They're not that they conduct them habitually. So it's very automated, and they don't really have much control over it. And then there's other aspects such as, for example, metacognitive, inside, where there might be a difficulty of with confidence, how you create your certainty, and it's again, related to the doubts that I just mentioned. And people with OCD have more difficulty being confident about the decision, even though they have the same information as people without OCD.

Steve Flemming 19:20
So it's incredibly useful to have such a clear definition because as you say, there is such a misunderstanding, I think here in terms of the popular stereotype, and I'm just wondering, because another element of that stereotype is on the more clinical end of things is that it's connected more to hygiene, hand washing. And I'm just wondering what the, what the current thoughts are about the content of these obsessions and, and whether there's anything you can get out in your research on, on where that content arises from. So I guess my first question is, is that stereotype of it being very connected to hygiene? True or is that Again, a misunderstanding.

20:02
Yeah, so there are about four or five subcategories that the literature usually finds and hygiene and washing is one of them. I think it's one of the more common one, but it's not the only one, it's not the dominant one, I think checking is equally frequent. So the puzzle is a bit little bit that there's only the actual content is seems to come more accidentally, then we could really link you know, like, hand washing is linked to brain process a and checking is linked to brace process B, so that these approaches have been looked at and haven't really been successful. And also those, it's interesting to see that people that are affected by OCD, sometimes it changes over time, what kind of symptom it is, and usually it's more than just one. And the current explanation is, it's usually targeting something that is important to you. So it's usually kind of the obsession and the components are around something that is meaningful. And you can also trace that a little bit through the throughout the ages. So 100 years ago, it was much more youth related to religious content. And people probably with a stronger religious background are more likely to develop OCD, which are related to sin and, and religious content. And so it kind of Yeah, it just picks on the things that makes you anxious, which is really been

Caswell Barry 21:47
I'm really interested in, in this sort of first hypothesis, the port forwards through before it that it's doubt related, or maybe uncertainty related. Do we have any? Do we know anything about sort of the functional basis of OCD? Are there? Are there medications that work that give us pointers? Are there brain regions that are socially what is? How does it what's causing you?

22:12
What's causing? If I knew that, then

Steve Flemming 22:15
you'd be out of a job?

22:22
Well, yeah, we'll see whether I'll ever get there. Yes, so the there are different ways of thinking of OCD. And throughout the time that have different hypothesis has been for put forward. If you look at the medication, which people usually take as a hint for which system might be involved. So the standard medication is SSRIs, that medication that mainly affects the serotonergic system, and essentially very similar medication to what you should how you treat depression, often there, or sometimes they're supplemented with dopamine related trucks, such as Risperidone. But there is fairly limited evidence for either of the system really been affected, and in particularly the assumption that serotonin is kind of one of the causes is not very much evidence. So the idea would is often that serotonin might help but you know, you can you can break a system in one way and then try to mend it with another way. And that's my how SSRIs work, as they also do in depression, I think. I think there is. Well, one of the more interesting hypotheses is related to dopamine, and dopamine dysfunction. I think that was probably put out there 20 years ago, still, the evidence is relatively limited. Mainly because we're limited in how we can study it, it's very difficult to get any animal model of OCD because of the obsessions, these thoughts you can't determine whether a mouse has. So we're limited to what we can do with human neuroimaging. And so we can see that certain brain regions light up and we know that they're more

likely to be innovative. I don't mean, but as all the circumstantial evidence we have. And indeed, we see that it's mainly from strike loops, which are affected if we talk about the neuroanatomy and we know that they are tightly linked to dopamine functioning. And so I think that's where probably the strongest evidence comes from. So the idea is that there are these loops between the Olympic striatum so areas deeper sitting deeper in the brain, and mainly the prefrontal cortex. So the thing that sits above your eyes, which is critical for thinking and more complex computations, and these loops seem to be somewhat out of order, at least that's what most of the evidence is showing. And in our own work, we have shown that such like reward prediction errors that I mentioned at the beginning to RL, that they are different in activity in OCD compared to healthy controls and colleagues from Cambridge and actually took it a step further and so that if you administer dopamine, then you can norm kind of normalise these alter prediction errors in OCD. So that's probably the best evidence that there might be this aberrant processes linked to OCD.

Steve Flemming 26:02
And do you think that that influence or dopamine is going to be reducing the obsessions? Or you keep having your obsessions, but you're just less likely to be worried about them or act on them?

26:15
Yeah, I mean, that is like that is very much out there. And we don't have no idea how how, and this is really, this is a critical thing, right? So we, on the one hand, we have this brain mechanism, understanding, we know how certain information is processed, but then how do we translate that to an experience that someone has the symptom? And this is kind of the main gap that we try to bridge, which is really challenging? And so we're not quite sure is the short answer, the longer slightly longer answer is we try to kind of look at symptoms, try to break them down and try to understand how could we, how could information processing and our our model goes wrong in order to give rise to the symptoms? And so you could think of a hyperactive prediction error system. So with a system that always tells you, you're wrong, even though you're right, or that makes you doubt what you're what you know, and that may be makes you less confident, and it made me make you go ahead and check more and more, because you're constantly thinking you're wrong. And so that is one of the ideas that people have put out there, including us.

Steve Flemming 27:41
And just, as you mentioned, the challenge of animal models in this area, we're just thinking out loud, slightly wacky idea, could you not have an animal model where you kind of just index a state with a neural marker and then just see that the mouse is always stuck in that state? Has anyone been thinking along those lines?

28:03
Not that I know of. So what they usually because it's difficult to do define the states, right? So it sounds maybe a little bit like working posttraumatic stress disorder where you expose them to like a stress inducing state and then you have it recall reappearing? Which, yeah, it's probably a different process from what OCD is doing. So there are some motions that suggest that there might be a traumatic event, which is triggering it, but I think the evidence is fairly weak. And I think it's more likely that there is no trauma related to it. So it's then an animal model where you traumatise it in a way, is that an adequate

model? And so the standard animal models, they usually just have the look at repetitive behaviours like grooming behaviour, as a proxy, but obviously that grooming behaviour, and is that really driven by these same obsessions, or is it just a more of a motor process that we don't know. And it's difficult to judge?

Caswell Barry 29:10
Are they clear? I mean, are they clear factors that contribute to the development of OCD? Like for example, do we know if there's experiential, environmental genetic factors that predispose you to developing it or is it totally unpredictable?

29:24
Yes, no, no, there is clear predictions. I think, with OCD as it's probably most other mental illnesses you go you assume that or we assume that there is a bias, psychosocial model there. So they're clear. So OCD has a high heritability. That means it runs in families and you have you very often see that, that if you have a patient coming in, someone in the family also has OCD or very strong OCD traits and There's definitely a genetic aspect to it. Again, which genes exactly are playing a role, it's very difficult to say. And as with many other mental illnesses, when you try to use just gene to predict whether someone gets ill you don't get very much variance explained to you're not very good at predicting just on the buy jeans alone. There's definitely environmental influences as well. And probably socialist as everywhere, you know, if you have very good support system that helps prevent, and you have psychological factor to spec, your resilience, your reaction to stress and so on, so forth. But yeah, it's not one single one, one single cause, but lots of different ones.

Steve Flemming 30:50
So I was wondering if you could tell us a bit about the most exciting thing you're working on right now, maybe not the most exciting if you want to keep that under wraps, but a an exciting project that you're working on at the moment?

31:03
Yeah, I think what I'm very excited about at the moment, is to really understand this in a developmental context. So as you said, in the introduction, my lab is called to develop into computational psychiatry. And I think that is something that the field is still neglecting, which is that OCD in particular, but many other mental illnesses arise really during like early development. And so in OCD, you often have an onset at around the start of adolescence. And so, the core trying to understand what is it really that makes this time period such a vulnerable time period. And so to try to understand that, we are trying to really look at developmental studies. So because we know all of these behaviours, like the reinforcement learning and tasks associated and the cognitions associated with them, they undergo tremendous changes during the from childhood to adulthood. And so when we if we want to really understand the causes that or the vulnerabilities that might give prices would I think we have to take this development last angle. And so we've done a lot of work, just looking at like how this process is actually developing with age. And what I'm very hoping, really hoping to do is to trace that longitudinally, so that we look at the same young people and follow them over the years and to see what are the determinants that can tell whether someone is going to develop the tea and OCD or not, that is more of like a long term vision, actually, where we're working towards, because there are lots of

bits and bobs that need to be in place in order to do that. So we need to be able to measure these tasks. And these behaviours in a in a reliable and crude manner, needs to be accessible, and so on. And that's where we, for example, have developed the brain explorer app, which is an app for Android and Apple Store rate, which you can just download. And we've turned all these tasks that we usually do in the scanner, into games that you can play short form games on your iPhone or Android device. And by playing these short games, we can collect data. And by doing that we can collect 1000s and 1000s of people across the globe, essentially, we have people from all over the world. And we can actually then not own not only look at it development, but also we have a better representation of the actual population, which gives us better insight into OCD and the development of OCD. So that's where we are currently really working on.

Steve Flemming 33:51
And you're actively recruiting for that. So people should go to your website, and they can play the game.

33:56
Oh, yes, definitely. So if you're interested, or if you have kids around or anyone just tell them, you can go on brain explorer dotnet and download it or directly on your app store and enter brain Explorer, and then it should pop up.

Caswell Barry 34:13
You heard it here first, go download. Exactly. So to me is I mean, this is a really fascinating field that sort of merges research, direct medical applications. How on earth did you get involved in it? Was that what was what was your route into this? Or maybe I should go back even further. Like, what point did you did you know you're going to be working on this sort of field? Is this a long held ambition or is this something you stumbled on later in life?

34:40
Yeah, I never planned for this. I think I was I was very interested in understanding the human mind but I think that was driving towards the end of my towards the end of my high school years. I was really trying to understand what what it was going on in in people's minds, so I studied psychology at first and I was very interested, like more clinically oriented. And I think I remember I had to offer my undergrad decide where I will go more towards cognitive neuroscience or psychoanalysis, those were my top two topics. And it was it was a close call, but then I decided to go towards cognitive neuroscience. So that's where I got acquainted with brain imaging and brain research. But I think I always had a very strong interest in mental health. I worked quite a bit in in journalist and psychiatry in different roles. And there was always the idea I think, was, you know, I got to do a psychotherapy education training afterwards and become a psychotherapist or something. And by doing some, I think, doing internships along the way, I also got really excited about research and got like unique chances to work in collabs. And so towards the end of my master's, I just thought, well, it would be cool to do some neuroimaging in journalists and psychiatry. So combine both and then afterwards, I can always still do my, my psychotherapist training. And so it just happened to be that there was this fantastic opportunity in journalists and psychiatry in Zurich to do exactly that. Where I also got exposed to, or expose myself to computational modelling. And so I did my PhD in that field. And and kind of it was very cool. I liked it.

And, yeah, I think it really got sucked into it. And that's when I then decided that I want to know more about the methods and get better with that. And that's when I then came to UCLA. And I guess the rest is history.

Caswell Barry 36:56
Is there anything you do differently knowing what you know, now and you have any dead ends or ways you could sort of leapfrog further down? Would you just do something totally different?

37:06
Yeah, I am. I mean, hopefully not too many psychologists will listen to that. But I am not quite sure how much I learned in undergrad psychology. To be honest, I think there is. I mean, it's also 20 years ago, so the curriculum was quite different. And anything neuroimaging or biology related is, is probably more embedded now. But I think what I, in hindsight, I think I should have done more is more neuroscience training, as well as more, you know, mash analysis, computation modelling. I had like a focus on that during high school, but then I kind of abandoned it completely. And now it's really hard to learn it when you're my age. But yeah, that's definitely like more computational oriented, I would have loved to do more of that.

Steve Flemming 38:03
Just to public service announcements, plenty of neuroscience in the UCL undergraduate psychology. So I'm wondering whether Do you still have kind of, do you wonder what would have happened if you'd gone down the psychotherapy route? And do you think you might want to pursue that, again, in the future is something you've kind of wanted to, to have a string to your bow?

38:30
Well, I think I would have enjoyed that other job as well. I guess, yeah, I think it can follow more of my like colour can follow my curiosity more in in the job that I have. So I definitely don't regret it. I am trying to work more closely with clinicians as we go along. Because this is really difficult, I think. And it's really essential to bridge to clinicians like the insights that psychotherapist and clinicians have, you know, they're often implicit understanding of how something works can be a really valuable source for us to start modelling and put it into computational models. And I think that that is some proof that I want to pursue like to be more and better at relating to people. I am afraid it's probably a bit too late. Or at least at the moment, I don't have the time for a full psychotherapy, training, but you know, still have a couple of years and maybe after retirement.

Caswell Barry 39:37
That feels like a good endpoint, right? I feel like I feel like we've come full circle unless there's, unless there's anything else you want to tell us that's been a big influence on your life or that you know, that we should we all and our audience should know about working in this field.

40:00
Mmm, no, I think we covered many different aspects of it. I'm very happy with that. Yeah.

Caswell Barry 40:06

Okay, in which case, there is time for the thing that we ask everyone. So we're about to wrap up. But before we do, we'd like to ask each of our guests the same question. And that question is this. What is your favourite fact about the brain?

40:24
Yeah, so as I said, I was very interested in development. And it's amazing to know that the brain develops for a very long time, you know, 30 years ago, people thought when children were born more or less dense, that's it, and then the brain is fixed. But obviously, that's not the case. So my favourites fact is that we talked about dopamine and these dopamine projections, going from the brainstem to the prefrontal cortex and so on. And it actually turns out that at least in animal models, these so called mega cortical connections are amongst the last one to develop. So they grow throughout adolescence, which is really cool. So they kind of connect from the midbrain, first to destroy it, and then sit there for a while and then continue going on into the prefrontal cortex at the very late at late adolescence, and that can tell us a lot about what is going on, and how why people react differently to rewarding things or punishing things. And I think that's, that's probably the one mechanism that is developing the latest, at least as far as we know.

Caswell Barry 41:43
Fascinating.

Steve Flemming 41:44
Thank you so much. Great stuff. Well, that was fascinating. And thanks so much, Tobias, for joining us on this episode of brain stories. We'd like to thank Matt Wakelin, Mayor Sapir and Travis martes. For their roles in taking brain stories from an idea to a fully fledged podcast with Patrick Robertson and UCL digital education for editing and mixing. Please do follow us on Twitter at UCL brain stories for updates and information about forthcoming episodes.