Science Studio Vol 006 (Guest Brian Smith)

Did you say something?

Can ignoring something be considered learning? Catch up with skydiver and Professor Brian Smith as he shares how his research in learning with bees teaches us new things about the importance of not paying attention, and busts myths about relationships in the hive. Not everyone is quite as sisterly as you might expect.

Transcript

Peggy Coulombe: Hi, this is Peggy Coulombe from the School of Life Sciences at Arizona State University. Welcome to Science Studio. With us today is Professor Brian Smith. He uses insect models to study how learning occurs and how memories are made.

One of the things he is specifically examining is the importance of not paying attention. Welcome, Brian.

Brian Smith: Well, thank you.

Peggy: Now some people are probably wondering if they heard me correctly when I said, you study the importance of not paying attention. Tell me, how can ignoring something be considered learning?

Brian: A lot of animals are overwhelmed with stimuli all the time. They have lots of different sense that they can use to process information. And really, when you think about what it is we have to pay attention to, for example, as humans, it's a tiny fraction of the number of things that we could possibly be paying attention to at any given point in time.

Most people's concepts of learning are that you learn the association of certain stimuli with other stimuli that are important. They mean food. They mean mates. They mean predators. They mean good things. They mean bad things. Things we want to approach. Things that we want to avoid.

We use the associated stimuli to predict these good things and bad things so we can be prepared for them. In Pavlov's sense, a dog uses a bell to predict the occurrence of food. And soon the bell occurs, and the dog begins to salivate. The salivation prepares the dog to consume the food. That's the standard way of interpreting that.

But there are lots and lots of other stimuli around that the dog can't be paying attention to, because if it did, it would impair its ability to learn to pick out the bell as the most important stimulus. Of course, the dog is sitting in a highly controlled chamber at some point, just like all of the animals in any research lab where we're studying learning.

We really have to control the stimuli around them, because if not, they might be paying attention to the wrong things, and that would delay the time it takes them to learn something.

So one of the things that interested me, mostly because, to most people, it would be counterintuitive. That is, how do animals learn to ignore the wrong stimuli and pay attention to the right stimuli?

And when you get into the literature on the subject, and there is a vast literature on this, it turns out that this is a very important, active learning process. That is, learning to ignore things.

And there are various ways of doing it. Several different mechanisms, if you will, have been identified in the psychological literature. They range from simpler, and notice I'm using 'simpler,' not simple mechanisms like habituation or habituation to a stimulus.

That is, if I were to, in my classroom for example, have a little flashing strobe light that's not too intense, that would go off periodically, students would pay attention to it. And then sooner or later they would ignore it. Because it doesn't mean anything.

And that's a simpler kind of way of learning to ignore things. Certainly far more complex ways are what human psychologist would call selective attention.

Where I can selectively, in a cognitive, almost conscious sense, look at something and pay attention to it and decide to ignore it. And then 30 seconds later decide that, whoops, I was wrong, and then suddenly refocus my attention on it. That's a much more sophisticated way of doing something similar.

So there are various ways of doing it. And it turns out to be a very important kind of way of keeping us, also keeping animals, from being overwhelmed with information.

Peggy: Now I understand that you work with insects. Why are models for learning in insects, like bees, important?

Brian: Well, bees learn. Bees have to do very sophisticated things. They don't come into the world knowing everything that's important to them. And one of the things you have to think of, you don't need a huge nervous system to learn. I can get two nerve cells growing in a dish that make contact with each other, I can get them to learn.

You don't need a big, sophisticated nervous system to learn something. Yes, bigger nervous systems are perhaps more sophisticated in the types of things that they can learn. They types of attention they can implement. Selective attention might require a bigger brain than a smaller brain, in some sense.

But even small brains can learn. And we can learn a lot of principles of how things work from tiny brains. The example I like to use is, if I wanted you to understand how a computer works. I could take a very expensive computer and put it down on your desk, and you have to take it apart and you break it.

And then pretty soon I'm spending thousands of dollars for another computer, and you break that one. Then I'm spending thousands of dollars for another computer. And you break that one. And you learn, slowly. But it's expensive.

On the other hand, we can take a smaller computer that's far less expensive, like a hand calculator, that to some extent does the same thing. Maybe not as sophisticated. Sure, I can't run a word processor on a five dollar hand calculator, but I can understand how you can add two plus three and get five.

So I can understand the principles of how things could work, and use it to guide my investigation of the bigger computer. Now ultimately, I find perhaps that the bigger computer doesn't work the same. But that's fine, because at least when I'm investigating the bigger computer, I have specific hypotheses that I'm looking to investigate. So I'm not feeling my way around in the dark, in some sense.

Peggy: And I could break the smaller calculators, for example, to find out all these things.

Brian: Yeah. And I'd much rather buy you a five dollar hand calculator than a $10,000 Macintosh or whatever.

Peggy: [laughs] So what led you to bees in particular?

Brian: Well, I used to think I wanted to on vertebrates when I was much younger. Probably one of the most fascinating courses I ever took in my entire life was a course on invertebrate zoology. In some sense, when you look at a mammal and see that they are doing something that looks reasonably intelligent and impressive, well, OK. They have big brains. They're mammals, and so on.

But when you look at something really tiny, and an insect like a honeybee already has a very big brain for an insect. It has about a million neurons in its brain. We have a million times a million neurons in our brains. So our brains are about the equivalent of a million honeybees, if you want to think about them that way. That's not completely correct, but.

So when you see a honeybee that's about an inch long flying out from its colony and not knowing where the latest flowers are coming into bloom. Those flowers, of course, contain the nectar and pollen that is the carbohydrate and protein resources their honeybee colony needs.

This tiny little bee has to fly out somewhere within a few mile radius of its colony. Which, when you think about it, if you calculate the area it has to cover, is huge. And that bee may fly a very, very convoluted path out as it's looking for something. And then suddenly, it finds a tree that wasn't there yesterday. Or the tree was there, but it wasn't blooming yesterday.

That bee now has to go back to the colony, collect the nectar and pollen. It has to fly back to the colony. Well, does it fly back on the same circuitous route it took on the way out? No. It makes a straight line.

Peggy: The beeline.

Brian: Literally, that's where the word beeline comes from. And what that means is, what that bee was doing while it was making this very, very convoluted track out there, is it was keeping track of its speed and its rate of turning, and at all points along that path, calculating its straight line trajectory home.

Not doing calculus, but solving it via some other means. That bee then goes back and does a specific kind of, well, it's called a dance. Inside the colony, to communicate where that tree is to its nest mates. And instead of taking them and pointing and saying, go in that direction. What the bee does is, it does a dance. And the angle that that bee makes while in a particular part of the dance, relative to the vertical in the colony.

Remember, it's dark inside the colony. Bees can't see. They can only follow this vibrating dancer. And the angle that they make with respect to the vertical, to gravity, is the angle that those bees have to take with respect to the current position of the sun. So if the bee is dancing 20 degrees to the right of vertical, the bees go out and see where the sun is, and they fly 20 degrees to the right of the sun.

What they're doing is using gravity, in some sense, as a symbol, or something else, which is the sun. And that, I wouldn't--it's been called the dance of language. It's certainly not a language in every sense that we mean it to be, or that we might think it would be. But short of that, it's just really impressive to see what they can do.

Peggy: So in the process, they're encoding all the information about how far away, and the angle relative to...

Brian: That's right. How long that straight run is, is correlated to how far the bees have to go. The angle with respect to vertical.

It's sort of like if I could take you, and put you in a completely dark room, where you couldn't see anything. But you're standing on a ladder, and I can rotate the ladder. You would know which was is up, right? And that's what bees are doing, to do that.

And furthermore, what they can learn. People have studied what they can learn. It's really, really impressive. I will lay down a wager that I can take anybody and have them come into my lab, and probably within 30 minutes or an hour, they could be training a bee. And it's impressive because you're talking to the bee. You're communicating with the bee. You're giving it something it wants.

You're understanding how it understands the relations between these stimuli that tell it something. And it's fun. It's interesting.

Peggy: So when someone might say to you that brain size was related to flexibility and capacity, would you be a proponent of that statement?

Brian: Not necessarily. As I said, you can take two nerve cells and get them to learn, right? They will modify their connections to one another based on what kind of associations you force them to make.

So when I say there are a million neurons in a honeybee brain, and each of those neurons makes about 10,000 little synaptic connections with each other, right? And learning and memory, in some sense, is a function of the number of those connections and how the can be modified. Suddenly the information capacity of a system like that is enormous. Right?

So I don't look at a tiny brain and think that they're less flexible. In fact, you could actually almost make the opposite argument. If we came into the world, or we're forced to come into the world, more or less knowing a large fraction of what we are going to need to know in our lives, we would probably need brains that are vastly bigger than the ones that we have.

So what we can do with our brains, is we can flexibly use our brains to learn what we need to know at the stage of our lives, that we need to know these things. Then we can forget them and use the same neural circuits to learn something completely different later, that's more relevant.

So we're very flexible about how we use our brains. And that lets us keep our brains small. So that's the opposite argument, is that it's not our brains are really big and that gives us the capacity to learn. Rather, you can turn that argument around as far as I'm concerned and say, the reason our brains are so small is because we can learn so well. And that lets us flexibly use things.

And why would we want to do that? Well, I'm not sure of the exact figures on this, but if you look at metabolic activity of most different kinds of cells in our body: muscle cells, skin cells, liver cells, nerve cells that make up our brains. As I understand it, our brains, and nerve cells or nervous tissue, is some of the most metabolically most costly tissue of our bodies.

I had a colleague once who was a physicist who made some calculation about how much--you know, when we walk into a room, you get a lot of people sitting in a room, and suddenly the room heats up because of body heat. He calculated that quite a bit of the body heat is actually coming from neural activity.

So if my students are sitting in a classroom that's too hot, I tell them to stop thinking so much.

Peggy: [laughs] You're hoping that it's coming from neural activity.

Brian: Exactly. Right. But that has a serious side of it. If we're going to add brain size, it's going to be very costly for us metabolically. So that's really--the costs of adding nervous tissue are quite high. And that's another reason that we need to be very flexible in how we use our brains.

So small brains are forced to be very, very plastic. And like I say, a brain with a million neurons in it can do some impressive things.

Peggy: And with social insects, they have an advantage in that all those individuals' activities are linked as a hive. Is that correct?

Brian: Well, that's another interesting sort of statistic. When you think a colony might have 100,000 bees in it. Remember, each of those bees has a million neurons in its brain. So collectively, that colony has a brain about the size of ours. A little bit smaller, right?

But theirs is linked differently, because they communicate so effectively. We already talked about the dance. They can communicate. One bee can communicate what it knows to other bees. So the colony can effectively get out there and be the first to exploit this new resource before other colonies find it.

Well, their brains are connected. They're just connected in a different way. How many of us would love to just be able to send part of our brains out to do one thing, and another part of our brain out to do something else in a completely different location. That would be incredibly efficient.

Peggy: Yeah, I think a lot of people would sign up for that.

Brian: Yeah. Some people would send part of their brain to class, and part of their brain somewhere else. Like shopping.

Peggy: Like Aspen. They can go skiing.

Brian: Yeah, exactly. Right. Right. That's really what a honeybee colony can do. So that radius we talked about, the foraging radius of a few miles around every colony. Any given bee only know a tiny little part of that, because of its experience.

Collectively, that colony knows quite a bit about that huge area, because they can take the individuals, who are tightly linked because of their communication system, and basically have that information reside at the level of the colony.

Peggy: One thing came up when we spoke before this interview. Is that is that all bees from one colony are not necessarily as closely related as we all imagine. Can you tell me how that comes about?

Brian: The colony is headed by a single queen who lays all the eggs. So one might normally think that all the bees in the colony are sisters. Right? Well first, something that most people listening to this might not know, is that most of the bees in the colony are workers. Workers are female.

What that would mean, under normal circumstances, if the queen lays all those eggs, would be that those bees are sisters, closely related. The colony produces males, which are called drones, only at certain times of year, during mating season, for example, when they're also producing new queens. Otherwise, the workers are all female.

What most people don't realize is that when the queen mates, she may mate with anywhere from 10 to 20 drones, maybe even more. And she stores the sperm from those drones in a special area called a spermatheca. Those sperm stay alive for several years, and she can use those sperm to fertilize all the eggs that she is going to lay in her lifetime, which is a huge number of eggs.

If she lays 800 eggs a day, and you figure a queen might live for two to three years, you can do the math and figure out how many eggs she lays. That's a lot.

But given the fact that she's using those sperm almost randomly, the sperm from different drones. What it would mean is that the composition of workers in a colony may stem from the same queen, assuming that queen has headed that colony for a long time. But they may have among them 15 or 20 different fathers. These are called patrilines. Paternal lineages.

The genetic relationship, then, among those workers, is greatly reduced, because they have different fathers. So that, and this is a project we did a few years ago. If you try to train bees in a colony, you'll find for most kinds of learning protocols that you might develop, a lot of the bees will do fine, but there will always be bees who don't do it as well. I never thought of them as stupid bees.

So one of the things we found over the years was that the genetic variation from their father, really explained a lot of the variation across individuals in how well they learned. So they are genetically, if you want to think of it, differentiated or specialized to learn different kinds of things.

So I don't say that they're stupid. Rather, I'm the one who's not asking them the right question.

So one of the things we're looking at in our lab right now is why does this variability exist? We're following up on some work by my close colleagues here, Page and Amdam and so on. They've looked at this in far greater detail than we have. That is, this genetic differentiation within a colony, and what it might possibly mean.

So we're looking at this as perhaps the existence of a syndrome of behaviors. In their case, they're looking at foraging. Learning as related to foraging. So we're trying to look at how our genetic variability of learning might relate to their studies of foraging, for example.

Peggy: Now when we spoke before, you told me that bees did different tasks. There was specialization in foraging for example and that some bees were quick learning. They would go to a particular source, but they would lose interest in it pretty quickly. And then some bees were slower to learn.

Brian: Oh, right. Right.

Peggy: Could you elaborate on that?

Brian: Well, this is just purely hypothetical at this point. And one of the things that we're looking at is, as we spoke earlier, is that I'm interested in how bees learn to ignore things. There's genetic variation in the speed with which bees learn to ignore things.

We're trying to right now map the genes that are different in those bees that cause them to quickly learn to ignore things or to more slowly learn to ignore things. One of the ideas is that, if you imagine a bee goes out and it flies its little circuitous path out. It finds a tree that's just come into bloom.

Now it goes back and it recruits, through this dance behavior, a lot of its nest mates, to come out and help exploit the nectar and pollen given off by that tree, because it's just come into bloom.

Now when these bees actually get out there, all of them, they will find that most of the flowers have nectar in them, let's say. But after they have been exploiting this little patch of flowers for a little while, and maybe bees from other colonies come in and start doing it too, then the flowers will become depleted. So more and more often, with increasing frequency over a period of time, a bee lands on a flower and find nothing.

So what I think is happening, and this has yet to be shown, as I said. Is that there are some bees who really, really learn to ignore things fast. So when the situation changes and they stop getting reinforcement, they leave.

There are other bees who learn to ignore things much more slowly. So they are much more tolerant of not finding nectar or pollen, whatever it is they're looking for. And they keep going.

Well, those are the bees who are going to stay and really pick up on the last dregs of what's left. Whereas the ones who take off because they don't like this idea of not finding something, they're going to be out finding the new things that have just come into bloom.

So, at least in a hypothetical sense, you could think that this might be a way of a honeybee colony to much more efficiently exploit what it knows about the world. To get the last little dregs of the nectar or pollen, while at the same time taking a smaller fraction of it work force and saying, well, you don't worry about exploiting things. You're going to go off and find the new things that these other bees are going to be recruited to.

So I think it might be a way, at the level of the colony, to be much more efficient.

Peggy: Now moving away from bees for a second. I understand that in your spare time, you do a number of activities: skydiving, swimming, and yoga. And to tell you the truth, I always think of yoga and meditation as being totally different from jumping out of a plane. So tell me. How are these two things related?

Brian: Well, in some sense they're related through me, because I just simply like them. They're fun. So they're related at different levels.

A lot of times I tell people, when I'm hanging on outside of an airplane and I'm about to let go, you might think that that's the most frightening part. But the sensation, I tell people is, it's like a laser beam in my head. I am so focused on what I'm about to do. I'm not thinking about or worrying about anything else. So I'm completely focused.

A lot of students, when they first start skydiving, they have to learn to do that because it can be such an overwhelming sensory experience. In some sense, you could say they haven't learned to ignore the right things yet.

Peggy: [laughs] Like the ground and how many thousands of feet below it is.

Brian: Like the ground. The only thing you have to focus on, when you're standing outside of an airplane. The airplane is moving at 100 miles an hour. When you let go of the airplane, you're going to quickly transition into free fall, where you're falling somewhere between 100 and 120 miles an hour.

Now most people, when they're driving down the highway, have rolled down their window and stuck their hand out the window at 60 miles an hour. And you know if you hold your hand flat against the 60 mile an hour air, you can feel the pressure and how hard it is to control your hand.

Well, imagine now if your entire body is getting hit with a 120 mile an hour wind. If you're stiff as a board and completely inflexible and not thinking about what you're doing, you're going to act like a stiff board and just start flipping around all over the place out of control.

Whereas, if you start to relax, one of the most counterintuitive things. I'm full of counterintuitive things these days.

Peggy: [laughs]

Brian: The most counterintuitive thing you can tell a student who is learning to skydive is, relax. Why is that? Well, the wind is going to push you into the most dynamic controllable body position you could possibly be in. And that's basically a backbend in yoga. Where your center of gravity is low. You've got equal pressure all over your body. And it's a very, very fundamentally stable position.

In fact, if you tell someone who's unstable in freefall, if you tell them, do a backbend, they'll automatically flip right over from whatever position they're in, into a very stable body position.

So the nexus, if you will, between skydiving and yoga, is control of your body position. If you are good at yoga, I can almost guarantee you you'll be good at skydiving, because you can do backbends. A turn in skydiving, is a twist in yoga.

Peggy: Is some of that control of the mind, as well? Focus?

Brian: I was just getting to that. The focus that I feel when I do yoga, in terms of trying to get myself into the right body position, in terms of--and sometimes you get into positions where it might be a little painful. It's hard to get into it. And you begin to think, control breathing. Control your breathing. Focus.
A lot of times, if I'm trying to balance myself in yoga and I'm falling over. It happens a lot. And I suddenly realize, I'm working so hard that I'm practically holding my breath to

really force this posture. And suddenly when I think, breathe. Breathe regularly. And focus on my breath first. Then suddenly it works.

And I think it's learning to focus your mind. Learning to focus your mind. Learning to control your body. And learning to understand the relationship between that mental state and the physical state. That's very much a part of yoga, and one of the thing that interests me about it.

It's controlling the mental state. It's relaxation in free fall. It's controlling your body and using your body to control the movement through air. So I do see that there are some very, very close and deep relationships between the two.

Peggy: So what is the most exciting dive that you've ever done?

Brian: The most exciting? Well, there are lots of them. All of them.

Peggy: Well, let's say, how many dives have you made?

Brian: Oh, about 1,700.

Peggy: Oh, my gosh.

Brian: Some of the more memorable ones: I like to do formation skydiving, which means I jump out of an airplane with lots of people, and usually it's four or five. But I went to do what's called a big way camp one time, where you're learning how to do large formation skydiving with lots of people.

So I went through four days of this camp, and at the end, the people announced that later that year, they were going to do a big formation with 120 people in it. And I had done a formation with maybe 30 people in it, and I thought that was huge.

And I went up, with all humility, I went up to the organizer and I said, someday I would like to do something like that. And the next day he came back and he said, well, we looked at you on videotape, and how about you come back and come out and do it.

Peggy: That's wonderful.

Brian: Yeah. It scared me, though.

Peggy: [laughs]

Brian: So one of my more memorable dives was the very first time I jumped out of an airplane that was flying in formation with five others. Each of those airplanes had over 20 skydivers in it. I jumped out and saw virtually, what looked to be an entire city of people below me.
Then I realized where I had to be, and I was trying to get there. I didn't make it in the first time, but I did after that. So that was a memorable one.

Another memorable one was the time I jumped off of a cliff in Norway recently.

Peggy: Yeah, you showed me a video of that. That was base diving, I think.

Brian: It's called base jumping. I've done one base jump. I went to take this class in Norway, and of course the fjords there can be quite high. And the idea was, we would jump off of a 3,000 foot cliff that was overhung by 150 feet. And I've jumped out of airplanes at lower than 3,000 feet, so I thought that was OK.

The day we were to do it, though, they announced that the winds were high and the weather was bad, and we couldn't go there. And would we rather, perhaps, jump off this 800 foot cliff that was not overhung.

Peggy: [laughs] That's a significant difference.

Brian: Yes, it was. So I thought, well, OK, I came this whole way. Why not? And I did it. It was fun. But yes, talk about a focus.

Peggy: [laughs]

Brian: One has a focus when you do something like that.

Peggy: With such a capacity to focus, does this sometimes get you into trouble at home?

Brian: Occasionally, yes. My children would probably tell you, in spite of the fact that dad does all these things, he's much more relaxed than he used to be. And I think it's good, because my son is 14. He has certain interests, and I like watching those interests grow.

And my wife and daughter, the same. My daughter just took up gymnastics, and it's absolutely amazing to see what she can do, and to watch her come home and do cartwheels and do yoga moves that I can only dream of doing someday with my aging body.

So it's fun that everybody has their own thing, and we can watch each other that way. So it's difficult at times, but it works.

Peggy: Brian, I want to thank you so much for taking time to talk with us today.

Brian: Thank you very much. It has been my pleasure.

Peggy: This is Peggy Coulombe. You've been listening to the School of Life Sciences Podcast Science Studio. School of Life Sciences is in the College of Liberal Arts and Sciences on the Tempe Campus on the campus of Arizona State University.