Brain Science with Dr. Ginger Campbell

Episode #125

Ninth Annual Review

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INTRODUCTION

Welcome to *Brain Science with Dr. Ginger Campbell*, the show for everyone who has a brain. I'm your host, Dr. Ginger Campbell. This is **Episode 125**, and it is our Ninth Annual Review episode.

The goal of the *Brain Science* podcast is to explore how recent discoveries in neuroscience are helping to unravel the mystery of how our brains make us who we are. In this episode, I'm going to be going back over some of the key ideas and topics that we have discussed in 2015.

This year, I released ten new episodes and talked with eight guests, including philosophers, clinicians, and basic scientists. We discussed eight different books. After I review these key ideas, I will talk a little bit about what to expect in 2016, and then I'll close by giving you a little information about how you can help keep the *Brain Science* podcast going.

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DISCUSSION

We started out the year in Episode 115 by talking with Dr. Evan Thompson about

his new book, *Waking, Dreaming, Being: Self and Consciousness in Neuroscience, Meditation, and Philosophy*. This is the second time that Dr. Thompson has been on the *Brain Science* podcast. I talked to him back in Episode 89, when we talked about his last book, *Mind in Life*. But, Evan Thompson is probably best known as a co-author of *The Embodied Mind*, which was one of the pioneering books that helped to launch the field that is now known as embodied cognition.

In his new book, *Waking, Dreaming, Being,* Dr. Thompson give us a very deep discussion of how Eastern philosophy of mind and Western neuroscience can challenge and inform one another. It's not an easy one to summarize, but I think that the key question that Thompson addresses in this book is *what do these different states of consciousness tell us about the mind and the process by which our brains generate our sense of self?* He does this by comparing what Eastern meditation-based traditions say to the discoveries of Western neuroscience.

Dr. Thompson does have a longstanding interest in Eastern thought, but he considers the scientific method to be our best tool for choosing between alternative positions. We actually talked a little bit about the Dalai Lama's rather unique position, because he clearly embraces the scientific method, but then he has to confront the possibility that some of his Buddhist teachings won't stand up to this testing.

Western neuroscience has tended to have a rather narrow view of consciousness, but Eastern thought has always considered states like dreaming to be equally important. Back in Episode 67, Thomas Metzinger made the point that studying these various altered states is essential if we're going to develop a truly comprehensive theory of how the brain generates the mind, since obviously the mind is active during things like dreaming.

Waking, Dreaming, Being takes us through various states such as dreaming,

lucid dreaming, deep sleep, and even near-death experiences, with a focus on how our sense of self changes during these different states. Lucid dreaming just means that you're aware that you're dreaming. This is something that scientists are just beginning to study. One important implication of its existence is that it challenges the idea that dreaming is a mere epiphenomenon. We still don't know what it's for—that is, dreaming—but the evidence is mounting that it has some sort of physiological purpose.

One of Thompson's overriding themes is the idea that self is a process, not a thing. And while Metzinger sees the self as an illusion, Thompson argues that not all constructions are illusions. We know that the world isn't exactly the way we perceive it, but that doesn't mean it doesn't exist. These differences in interpretation remind me of the two points of view in Eastern thought—the difference between the idea of no self versus the idea that the self is not permanent.

Another key idea, which we actually talked about with Dr. Robert Burton back in Episode 96, is that we can never study consciousness from the outside. And this presents fundamental limitations. It's also the reason that Thompson feels that Eastern meditative traditions have something to offer Western neuroscience. Meditation provides a reproducible tool for experiencing consciousness in a structured, attentive way, which can then allow neuroscience to construct experiments that determine what the brain is doing in these various states.

For example, we know that it is possible to reproduce out-of-body experiments by stimulating certain parts of the brain. It's also possible to reproduce some of the experiences that have been reported with near-death. And I mentioned, at the end of this episode originally, that for those of you who don't want to read the long version of this book, Dr. Thompson did release an eBook called *Dying: What Happens When We Die?; A Selection from Waking, Dreaming, Being*, which just contains the episodes about near-death experience.

In Episode 116, I talked with Dr. Norman Doidge about his new book, *The Brain's Way of Healing: Remarkable Discoveries and Recoveries from the Frontiers of Neuroplasticity*. This is Dr. Doidge's second appearance on the *Brain Science* podcast. I talked to him back in Episode 26 about his first book, *The Brain That Changes Itself*. This book was actually a best-seller and is the book that introduced a lot of people to the idea of brain plasticity.

One thing I particularly enjoyed about this year's interview was getting to know a little bit about Dr. Doidge's background. I didn't know that he had studied under Nobel laureate, Eric Kandel, early in his career, and I was fascinated to learn that his interest in brain plasticity actually came from being immersed in the world of learning disabilities. This is a field where, as far as I know, treatments based on brain plasticity are still not mainstream. He did mention the work of Barbara Arrowsmith Young, which was featured in *The Brain that Changes Itself*.

His first book focused on some of the scientists who proved that the brain is actually plastic throughout life, but this new book focuses on clinical applications of this discovery. Now, many of these treatments have been dismissed as fringe or quackery, partly because they go against the still rather ingrained dogma that our brains can't really change after childhood.

Now, the idea of brain plasticity goes beyond just the discovery that our brains have a limited ability to make new neurons. The more important discovery, according to Doidge, is that the brain's ability to heal rests on its ability to form, unform, and reform circuits very rapidly.

Doidge also emphasized that developing new treatments will require a paradigm shift in the way we think about the brain. And this goes beyond just accepting plasticity. In his opinion, we have what he calls a "too material, too chemical, and too digital" view of the brain, and this has affected our understanding of brain damage.

What he means by 'too material,' is the fact that we tend to ignore that the brain's communication system is actually electrical and energetic. By 'too chemical,' he means that we tend to focus on pharmaceutical solutions, i.e., magic pills. And 'too digital' refers to the assumption that neurons are either on or off, which neglects the role of noise and the fact that damaged neurons probably play a huge role.

Doidge noted that the only time that neurons are completely off is when they are dead. Last year, Michael Merzenich talked about the role of noise in the aging brain and also about how approaches to reduce noise show great promise. Doidge and I talked about the relationship between a noisy brain and learned non-use. Many of the approaches discussed in *The Brain's Way of Healing* appear to work by reducing noise, often in ways that are completely non-invasive.

Doidge also talked about what he called the "too imperial view" of the brain, which is thinking of the brain as the place where all the action is, and the idea that the body is just there to serve the brain. Doidge says that the idea that you are your brain is "terribly, terribly wrong." After all, brains did evolve after bodies.

According to Doidge, the final problem with the current model is that it's too corticocentric, and that, rather than looking for higher functions in the cortex, we ought to be looking at the results of the interaction between higher and lower regions. After all, the cortex and the subcortex did evolve together by interacting.

Then we considered some of the clinical implications of these ideas. For example, there is some evidence of involvement of the basal ganglia and the cerebellum in autism. This was actually mentioned by Temple Grandin in her recent book. One of the implications of this involvement could be that kids who have subcortical problems are exhausted by trying to use their cortex to take up the slack.

This also explains the possible mechanism of methods that aim at subcortical regions, such as the use of sound and similar methods that are completely non-invasive. An opposite example would be if a person had a subcortical problem, some of these problems might be addressed by diverting cortical resources.

Doidge's book is full of diverse examples. One that we focused on was the story of Moshé Feldenkrais, who definitely qualifies as one of the pioneers of neuroplasticity. I picked him because I have personal experience with using the Feldenkrais method after my last hip replacement in 2002. Unfortunately, since his work predated current appreciation of brain plasticity, his methods are often still labeled 'alternative' by those who haven't taken the time to learn the full story.

After studying the work of a wide variety of practitioners, Doidge has developed what he calls his first attempt at forming a model of how brain healing might work. He sees it as having four stages: the cellular level, which might be an example where something like low-intensity lasers might help; the level of neurostimulation, which could be the target of sound and electrical treatments; neuromodulation; and finally, redifferentiation of brain maps. This last stage is the one that has been most well-studied so far.

We closed out our conversation with a discussion about how do you determine which approaches are valid. Other than recommending contacting the people featured in the book, Doidge's advice wasn't all that helpful. He inadvertently highlighted the fact that these new treatment approaches are currently available only to an affluent minority.

I suspect that we're at least a generation away from widespread availability of treatments based on brain plasticity. And time will tell which of the treatments featured in Doidge's book prove to be the most effective and which ones fall by the wayside.

At the time of this episode, I also made a few other remarks that were my take on things. As a physician, I think that one of the problems with these methods goes beyond acceptance by mainstream practitioners, insurance companies, and various aspects regarding money, to the fact that every one of the methods discussed in this book requires active involvement of the patient; they're not quick fixes. It seems that, at least at the present time, many patients would rather take pills that follow treatment regimens that require them to do most of the work themselves, with guidance.

Also, there are many people who are severely disabled and just aren't able to do these active regimens. But, as I said, the main thing that Dr. Doidge is trying to do in this book is to begin to feature the fact that clinical approaches to tapping into brain plasticity are going to require out-of-the box thinking and an openness to reconsider methods that we might have dismissed in the past because they didn't fit into our ideas about how the brain works.

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Episode 117 was one of the highlights of the year from my standpoint, because it is an interview with Dr. Michael Gazzaniga, who many consider to be the father of cognitive neuroscience. Dr. Gazzaniga has written quite a few books, but his most recent is called, *Tales from Both Sides of the Brain: A Life in Neuroscience*.

I mentioned to him during the interview that reading his work is actually what rekindled my interest in neuroscience—which, of course, led to this podcast. I also have a great deal of respect for his ability to share neuroscience via his writing.

Naturally, we talked about his famous research with split-brain patients. One key point that Dr. Gazzaniga made early on was the effects that were seen when the left and right halves of the brain were disconnected disproved the idea that the

mind is separate from the brain. However, unlike many neuroscientists who are admittedly strict reductionists, Dr. Gazzaniga embraces the idea of emergence while emphasizing that this doesn't introduce anything mystical or magical, it just recognizes that there are different levels of analysis and explanation.

Why does this matter? Dr. Gazzaniga said, "I think this is a very big question. It is essential in picking vocabulary that will allow accurate communication between the scientists who are attacking the question of how the brain generates the mind, especially if they're working at different levels."

I asked him what was the most surprising discovery of his career. And I have to admit, I was surprised when he said that it was the discovery of what he has dubbed the interpreter, which refers to the fact that the left hemisphere seems to generate the story of what's going on, even when it doesn't really know and, therefore, has to make things up.

Another thing I found very interesting was the fact that he decided to focus more on people in this book, because he wants young people who are interested in science to get a better sense of the lifestyle. The importance of cooperation and collaboration really comes through in the book. For this reason, *Tales from Both Sides of the Brain* is a book I would highly recommend to anyone who wants an inside look at a career in neuroscience.

On the other hand, if you want to get a feel for his current thinking about important ideas like whether or not we have free will, I recommend Gazzaniga's last book, *Who's In Charge? Free Will and the Science of the Brain*, which I discussed back in Episode 82.

As we entered the spring, I was in the most busy part of my year of a fellowship in palliative medicine, so rather than miss putting out an episode, for Episode 118 I re-released one of my favorite early episodes, which was a brief introduction to

neuroanatomy based on the book, *Beyond the Zonules of Zinn: A Fantastic Journey through Your Brain*, by David Bainbridge.

One of the things I love about this book is that it emphasizes how much our brains are similar to those of other vertebrates, while at the same time highlighting how we're different. Bainbridge starts at the level of the spinal cord, where the neurons are on the inside and the white matter tracts that carry the information to and from the brain are on the outside. Now, this structure makes intuitive sense, since the nerves have to come off the spinal cord at various levels along the way.

If you want to learn more about this, I recommend Episode 110, which is an interview with Frank Amthor , author of *Neurobiology for Dummies*. In that episode, we talked about how we are learning that the spinal cord is actually a very sophisticated structure, and in vertebrates with simpler brains, it does some very amazing things.

Now, as we move up the spinal cord, at the top there are three major divisions: the hindbrain, midbrain, and forebrain. The hindbrain consists of the medulla and the pons. Several important cranial nerves come in here, including nerves that contain auditory, or hearing information. The medulla is also essential to basic functions like heartbeat and breathing.

Then we move up to the midbrain. Together with the midbrain, these structures are called the brainstem. That is to say, the hindbrain and the midbrain together, or the medulla, pons, and midbrain make up the brainstem, because they are located at the bottom of the brain where it is connected to the spinal cord.

Several cranial nerves come in at the level of the midbrain. These control the muscles of the eye, and also cranial nerve II, which is the optic nerve, which contains visual information that's on its way to the thalamus. At the level of the

hindbrain and midbrain, the neurons are scattered in groups that are called nuclei.

Finally, we come to the forebrain. But on the inside, we still have scattered groups of neurons, or nuclei, which represent a more primitive structure than the outer layers, or gray matter, which form the cerebral cortex. The cerebral cortex has a unique columnar structure, which is thought to be vital to the incredible interconnectedness of the cortex.

During the episode, I mentioned that smell is the only sense that goes straight to the forebrain, and olfaction is cranial nerve I. If you want to learn more about smell, I recommend Episode 34 with Rachel Herz, author of *The Scent of Desire: Discovering Our Enigmatic Sense of Smell*.

One of the things I really like about *Beyond the Zonules of Zinn* is the discussion of the evolution of hearing, vision, and smell. As we come to the forebrain, it actually has several parts. The diencephalon, which he also calls the 'interbrain,' contains the thalamus and hypothalamus. Then we move up to the telencephalon, where we have the cerebral cortex, the basal ganglia, and the amygdala. The basal ganglia, the amygdala, the thalamus, and the hypothalamus are all deep midline structures that continue to have that primitive nuclei-type structure.

So, usually, if you hear the phrase 'subcortical,' the strict anatomical use of this phrase refers to the basal ganglia and the amygdala, but some authors will also include the cerebellum as a subcortical structure. Usually when I use the term 'subcortical,' I'm thinking about all the parts of the brain that are below the level of the cortex.

As you might imagine, neuroanatomy is a very challenging subject to discuss on an audio podcast. But I think that it helps to at least have a sense of the basic

structure, and that was the goal of this episode.

Episode 119 and 120 are two parts of an interview that I conducted with Dr. Edward Taub, who is the inventor of constraint-induced movement therapy, which is an important method for treating stroke and other brain injuries based on brain plasticity. I first talked with Dr. Taub back in Episode 28. This year, I actually got to meet him in person and then record this interview.

One of the reasons why it was so great to talk with Dr. Taub again is that it's always interesting to talk to someone who's had a really long career, because they can give you historical perspective. In the first part of the interview, we talked about Dr. Taub's personal background, and he explained how the pioneering work in neuroplasticity inspired and complemented his work with constraint-induced movement therapy.

In particular, he mentioned the importance of the work of Dr. Michael Merzenich. Merzenich and his team established the principle of use-dependent cortical reorganization. Of course, I've interviewed Dr. Merzenich a couple of times, but I actually introduced his work way back in Episode 10, which was the first episode I ever did about brain plasticity. If you use the *Brain Science* podcast mobile app, you will find Episode 10 included as a free extra along with this episode.

You can learn about Dr. Merzenich's and Dr. Taub's work in several books. One is *Train Your Mind, Change Your Brain*, which I featured in Episode 10, and the other is *The Brain That Changes Itself*, which I just talked about a minute ago.

We ended the first half of Dr. Taub's interview with a brief discussion of the key elements of CI therapy. These are: train the affected limb intensely; shaping; using restraint of the least-affected limb; and something called the transfer package.

All of these elements diverge from traditional physical therapy which focuses on teaching people how to learn to compensate by doing things with the side that works. Now, it's true they do work to help people strengthen the affected limb, but there's an unfortunate assumption that recovery is limited to the first three to six months after injury, whereas, CI therapy has been shown to work even fifty years later.

Shaping is a tool that comes from animal behavior, that hasn't really been applied to humans, even though the principles are clearly valid in many contexts. It is interesting that restraining the good limb, which is the most obvious element of CI therapy, is actually the least important.

Dr. Taub says the most important part is the transfer package, which is the key to taking rehab into the real world. And, not only is it the most important element, it's the element that's most often missing when other therapists try to copy CI therapy without proper training.

The second half of Dr. Taub's interview contains three key ideas. First, overcoming learned non-use is a critical component in the success of CI therapy. Norman Doidge would probably call learned non-use the 'dark side of plasticity,' since the nervous system seems to follow the rule *use it or lose it*.

Just like it can be demonstrated that both gray and white matter increase with use, not using an affected part rapidly leads to loss of mass, both in the muscles and in the brain area that controls that limb. This loss must then be overcome for successful rehabilitation.

I can't help but think that traditional methods that focus on using the good limb actually exacerbate this problem. But this principle also emphasizes why it is so important that patients continue to work outside the rehab setting.

The transfer package that Dr. Taub kept referring to is the method that they use

to encourage this. Basically, the patient has to agree that they're going to use the affected limb outside rehab instead of doing things in a way that might be easier, like using their strong side.

We talked about a spinal cord patient that he is working with, that has a very high spinal cord injury. And this was really interesting, because it shows that the principles of neuroplasticity can also apply to the spinal cord if it's not totally severed.

Dr. Taub is also using EMG feedback, which demonstrates the importance of being willing and able to combine techniques to fit the needs of individual patients.

The third key idea that we talked about in this part of the interview was that Dr. Taub emphasized that we currently don't know the limits of rehab. My friend, Dr. Michael Bernstein is an example of someone who continued to improve because he was willing to keep working after he left formal rehab.

But clearly, we need ways for these techniques to reach more patients. Even at UAB, where Dr. Taub works, most patients never receive CI therapy, partly because a lot of doctors don't know about it, and often because it's not covered by their insurance. Hopefully, this is less of a problem outside of the United States. But clearly, there also needs to be a better way to get more therapists properly trained.

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membership. Just go to audiblepodcast.com/brainscience.

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Episode 121 was the episode for those of you who were craving a real basic science type episode. In this episode, I talked with A.D. (Bud) Craig, about his book, *How Do You Feel?: An Interoceptive Moment with Your Neurobiological Self*. Those of you who are long-term listeners may recall that Dr. Craig's work has come up many times over these last several years, since he is acknowledged as probably the world's leading expert on the insula.

This book is not for the average reader, but our conversation was designed to give everyone a feel for some of the surprising discoveries that he has made, and also some insight into why functional neuroanatomy has valuable contributions to make to understanding how our brains make us human.

Just to review a few key ideas, first there is a specific pathway in the spinal cord called the lateral spinothalamic tract, which carries interoception—information about inside our bodies. This tract has long been associated with pain and temperature. But that is an oversimplification; it actually carries information from three different types of receptors—which is more than I am going to get into.

All of the axons in the lateral spinothalamic tract are small, unmyelinated axons, which is why it has only recently been possible to trace where they go. Craig's first surprising discovery was that this pathway goes to its own area in the thalamus, and then, instead of going to the main somatosensory cortex, the signals actually go to a deeper area known as the insula.

The pathway to the insula is unique to primates and particularly developed in humans. So, why does this separate pathway exist? Craig's work has established that this forms the sensory element of the autonomic nervous system, and that it

plays an essential role in homeostasis, which is how our bodies stay in a functional state.

After establishing that the autonomic nervous system does, in fact, have its own dedicated sensory input, Craig moved on to establishing the critical role of the insular cortex. Here, his conclusions are based mostly on imaging studies. One of the key features of the anterior insula appears to be integrating homeostatic signals from all over the body, which makes it essential to our awareness of our body and of our emotions.

We touched briefly on the implications of the fact that the insula gives humans access to much more information than appears to be available to other species. Not surprisingly, the insula appears to play an essential role in mental health.

Episode 122 was an interview with Dr. Fabrizio Benedetti, author of *The Patient's Brain* and *Placebo Effects*. Dr. Benedetti is probably the world's leading researcher on placebo effects.

This is an interview that you really ought to just go back and listen to if you haven't heard it. But one of the key ideas is that the way the term 'placebo effects' is used in clinical research is entirely different from the way that Dr. Benedetti uses it in his work, because what he is looking at is the neurobiological effects or mechanisms of placebos, whereas, in clinical medicine or randomized control trials, the whole goal of the placebo is to eliminate confounding factors like bias.

So, in a clinically controlled trial, you have a group that gets a so-called placebo, or non-active treatment, and the other group is supposedly treated exactly the same except for the treatment. And the response in the group that receives the placebo is considered the placebo effect.

This is in contrast to what Dr. Benedetti is talking about, where he is really basically talking about everything that happens in the patient's brain and body

that isn't caused by the intentional treatment, whether it's a drug or some other action.

So, from Dr. Benedetti's point of view, there is not such a thing as the placebo effect, but placebo effects, which refers to the fact that there are multiple mechanisms. For example, there is the effect of expectation, which is very powerful.

And, in Dr. Benedetti's work, he also makes a distinction between conscious and unconscious placebo effects. Under conscious placebo effects, he talks a lot about the role of expectation and says that it has at least two mechanisms. One is the reduction of anxiety; that people become less anxious once the know that they're getting a treatment. And the second is the activation of reward circuits in the brain; and he talked about that in some detail.

He also said that another important mechanism is learning, and this can be both conscious and unconscious. For example, if someone gets pain shots for several days in a row—morphine shots for several days in a row—and then, on the third or fourth day, they actually get placebo, a good percentage of them will have the same response as if they'd gotten the real medicine.

Interestingly, this effect can also be demonstrated in animals. So, again, from the clinical trial point of view, the placebo effect is any improvement that happens after you get a placebo, whereas, in Dr. Benedetti's neurobiological research, it refers to something that's happening in the patient's brain or body.

He talked about some things that aren't placebo effects, and these are the sorts of things that are really the kinds of things that are trying to be eliminated when you're doing clinical research. One is spontaneous remission. Another is a statistical phenomenon called regression to the mean. And then, there are the various kinds of biases, which is the thing that you'll probably be most familiar

with being the point of having placebos in clinical research.

In neurobiological research, they really look at placebo effects as a true neurobiological phenomenon. And this can only be studied in the lab, because they use different research techniques. As he pointed out, the clinical researcher isn't interested in understanding why the placebo works, whereas, that is the very question he wants the answer to.

During the interview, we talked about some of the experimental designs he uses and some of the discoveries he has made, including the fact that in Parkinson's disease patients, you can tell them that their deep brain stimulator is turned on when it's not, and they will actually have the same response in the neurons as if it was turned on. This is at the level of single cell neurons. So, it's a real biological effect.

The other example, of course, is the fact that pain relief with placebos can actually be blocked by naloxone, which is an opiate blocker. Which shows that placebo response to pain is an actual physiological response involving endogenous opiates.

And, as I mentioned, besides conscious placebo effects, there are also unconscious placebo effects, which are different in that they aren't affected by expectation. And these can be demonstrated in both animals and people.

But Dr. Benedetti said that the take-home message for clinicians is that their words, behaviors, and attitudes are very important because they actually move molecules in the patient's brain. The example that really brings this point home, for me, was the one where they showed that if you give somebody a shot of pain medicine, whether it be an opioid, a non-steroidal pain medicine, or non-opioid medicine, and you don't tell them that they're getting the shot, it works about half as well as it does when you tell them that you're giving them the medication.

I have used this story many times in the emergency room to talk to nurses about it, partly because I want them to also appreciate that the role of anxiety explains why people get almost immediate responses to pain shots sometimes, even though it takes longer than that for the actual medicine effect to kick in.

So, from the standpoint of Dr. Benedetti's work, placebo effects are real neurobiological effects. He is focused on what happens in the brain, but he's also studying other things like the immune system and pulmonary function, which is where some of the more unconscious effects can also be seen. Placebo effects are multiple, and they are real.

Episode 123 is an interview with Anthony Chemero about his book, *Phenomenology: An Introduction*. I actually recorded this interview a few days before my husband, Dennis, died unexpectedly on July 25th, which was why this episode was not actually released until fall.

I want to start out by mentioning that, although the phrase, phenomenology, might be somewhat intimidating, this is really a highly-readable introduction, both to phenomenology and to its relationship to the embodied cognition approach to understanding the mind. This book also shows how phenomenology has impacted our understanding of things like perception and cognition.

This book puts the key thinkers of phenomenology into historical context, but what I really appreciated was the chapter about Maurice Merleau-Ponty, because he was the one who actually engaged with the science of his day. I was actually starting to read some of his books, but I got side-tracked from this when Dennis died. But I hope to get back to it eventually.

In a way, phenomenology is a break from the common Western approach to philosophy, which puts the emphasis on the idea of rational thought somehow existing separate from the body and its environment. In contrast,

phenomenology takes experience as primary and asks why we experience life the way we do.

This brings us to the issue of embodiment, because obviously, our experience is directly tied to the bodies we inhabit. It also challenges the idea that thinking is something that just goes on inside of our heads. Heidegger's terminology can be quite off-putting, which is one reason why James Gibson's concept of affordances is so pivotal.

This is basically the idea that we see the world in terms of how we can interact with it. One thing that makes this idea so powerful is that it's easy to see how it can apply to other animals. For example, a bird might see a power line as a nice place to perch, while we see it as something we should definitely avoid touching.

It's also important to appreciate that phenomenology and psychology influence one another, partly because phenomenology started at the same time that psychology was trying to emerge as a scientific discipline separate from philosophy. This is another reason why Merleau-Ponty is so important, because he was deeply engaged in both philosophy and psychology.

In a way, I think we should consider Merleau-Ponty as something of a role model for the importance of doing interdisciplinary work. Chemero describes Merleau-Ponty as "careful thinking brought into contact with good science." A modern-day example is the philosopher Daniel Dennett. And, as Chemero noted, engaging with science doesn't mean that there are no more philosophical questions.

We talked briefly about how scientists and philosophers tend to see the world differently. But I guess I agree with his comment that everybody is smarter than the other team gives them credit for.

So, the first half of this interview was pretty philosophical, but hopefully it set the

stage for a discussion about what Chemero calls "phenomenological cognitive science." A key difference between the phenomenological approach and standard cognitive science is that the standard approach works from the assumption that the brain's primary job is to build a model or a representation of the world and then generate computations based on that model.

In contrast, phenomenological cognitive science questions the idea of the centrality of mental representations or mental computation. Instead, it sees thinking as engaging with the world. Chemero says that thinking is something we do, as opposed to something that happens to us. As he said, "Thinking is something we do, it is not something that happens in our brains."

The phenomenological approach is an embodied approach, which is something that I have discussed in many previous episodes of the *Brain Science* podcast. So, this discussion actually is a good lead-in to the last episode of the year, which I'll talk about in just a minute. But the show notes for this episode do contain links to all the previous episodes involving embodied cognition, which actually, I think, goes back to about Episode 15.

An important point that Chemero made was that no single theory is likely to explain everything. His position is that human beings do many things, and some of these involve representation, but many don't.

Another important point is the idea that the way we design our experiments influences our results. People can seem more like computers or more like oscillators, depending on the experiment.

Does that matter? Well, Chemero thinks that the embodied approach can have important positive social consequences. For example, by encouraging us to make our environments more human-friendly.

We also talked briefly about dynamical modeling. Here, there are two key ideas

to remember. One is that, although a whole range of phenomena can be explained with the same mathematics, it doesn't imply modeling of the environment, representation, or computation; it's just an explanation of how things change together over time. That's what dynamical modeling is.

Second, when scientists use complex math to represent something, such as what humans do when they play videogames together, that doesn't mean that humans are using the complicated mathematical model. The analogy he gave was that, although we use calculations to determine the trajectories of the planets, the planets don't calculate their trajectories. Another example that we didn't talk about is the idea of catching a fly ball, which, although you can make a complicated formula for this, is clearly not what we do when we are catching one.

One of the key ideas of this book is that phenomenology is not just an interesting bit of history, but it continues to have increasing relevance, especially for those who are pursuing embodied cognition. Chemero talked specifically about the enactive approach, which we have explored in the past with Evan Thompson. He credits Thompson for the insight that if you start with the idea that you are a living body, a lot of philosophical questions kind of melt away.

I always ask my guests for advice for students, but I asked Dr. Chemero a slightly different version of the question, which was how one might choose between a career in psychology, philosophy, or neuroscience. Naturally, we both agreed that it is wise to be well-read in all three areas. But when it comes time to make a professional commitment, his advice was quite practical: pick the one you love, not the one that has the best job prospects.

As I said, I think that this rather philosophical conversation with Anthony Chemero was a great lead-in to the final original episode of the year.

[music]

Episode 124 is an interview with Michael Anderson, author of *After Phrenology: Neural Reuse and the Interactive Brain*, which is a book that represents ten to fifteen years of research. It reflects Dr. Anderson's unique background, which includes training in philosophy, artificial intelligence, embodied cognition, and neuroscience. Again, this is a rather technical book, not for the average listener. But I think he did a great job of introducing the key ideas during the conversation.

Anderson described the book as being made of three intertwined stories: an exploration of how the brain is organized; a look at how organisms think about and are involved in the world; and finally, a look at how evolution makes sense of these two stories. We actually only talked about the first two of these threads.

Neural reuse is just the idea that parts of the brain—at every level, from the level of single neurons all the way up to the largest brain areas—these participate in multiple coalitions; which means that the traditional approach of looking for a one-to-one mapping between brain areas and functions is obsolete. We need to get beyond phrenology, because even the basic motor and sensory areas of the brain seem to participate in this principle of neural reuse.

The book contains many examples that back up this claim. One that we talked about was the example of *C. elegans*, the roundworm, which is a very simple organism that we've talked about many times on this show. It's important because we can see its individual neurons, and there are only 302 of them.

So, in the context of neural reuse, what has been discovered is that these individual neurons are used and reused to drive multiple behaviors, and they interact with multiple different partners in these different behaviors; which is to say that their connections are modulated in real time. In fact, I was particularly struck by the idea that individual neurons could actually do opposite things, like excitation versus inhibition. And this is without changing the wiring diagram.

Consider for a moment the implications of these discoveries in *C. elegans*. It has a fixed wiring diagram and only 302 neurons, yet the principle of neural reuse appears to be fundamental; which implies that neural reuse is a fundamental process that has been around a long time, predating, in fact, brains as we know them. It also reminds us that there is going to be a limit to what we can know from the anatomical or structural connectome.

I also want to review how this neural reuse framework differs from the traditional approach of the so-called cognitive revolution. The, what he calls "current canonical theory" of how the brain works, is that it's an information processing device that generates representations of the world and then performs computations on those representations. Which is exactly what Chemero referred to.

During our conversation, Anderson talked about the historical origins of this approach, and how it was a reaction to behaviorism, and also very much influenced by its co-emergence with computer science. But when they started to try to apply these ideas in artificial intelligence and robots, they discovered that these systems are very different from us, because things that are really easy for a computer to do are hard for us, and vice versa.

The embodied cognition movement grew out of the recognition that our physical bodies and how we interact with the world appear to be fundamental to how our brains work. We don't really need models of the world in our head most of the time, because we can interact with the real deal. We do work with representations, but these are usually out in the world, not in our heads.

We talked about some examples of abstract skills, such as math and language, and how these two are built on our ability to interact with the world. This brought up the idea of affordances, which we talked about with Anthony Chemero. Anderson said that affordances are "a relationship between an

animal's ability and stuff in the world. When you see what you can do with something, you are perceiving an affordance."

Anderson sees language as a collection of affordance manipulation tools. It's actually highly distributed in the brain, including areas involving social interaction. This is in great contrast to the traditional view of language being isolated to specialized modules. Instead, with language, we have a skill that probably uses more parts of the brain than any other.

We talked about the famous experiment where people with normal vision are blindfolded and taught Braille. Dr. Anderson mentioned that the occipital lobe lights up while they're reading Braille, suggesting that the visual area was doing the tactile work. Interestingly enough, when they have the blindfolds removed, they still have the ability to read Braille, even though they no longer seem to use the occipital lobe to do this; which implies that there is some sort of search strategy that the brain uses in order to pick an alternative circuit.

But this is just another demonstration that assuming each region of the brain has a single function is probably wrong. This particular experiment stands out because here we're talking about an area of the brain—the occipital lobe—that's generally seen as being hard-wired and purely sensory. But, as Anderson mentioned, once he started looking at the experimental data, he discovered that the overlap of the use of the various parts of the brain was rampant—much more ubiquitous than he imagined.

So, the bottom line is actually pretty straightforward. There's overwhelming evidence that every part of the brain participates in multiple coalitions and functions. And this means that to ask *where* a function is located or *what* a certain region does are probably the wrong questions.

We also need new tools to capture the complexity of what the brain is actually

doing. We only touched on this briefly during the interview, but in the book he does spend a lot of time on that important topic.

For those of us not working in neuroscience, it's important to realize that complex behavior doesn't come from individual specialized areas, it comes from complex coalitions. This means that the brain is organized and develops by finding different configurations of the same pieces of the brain that allow it to do different and complex tasks.

The process also incorporates elements of the body and environment, which is why the idea of neural reuse is consistent with embodied cognition. He noted that we are actually forming extended coalitions of brain parts, body parts, and environmental parts. He says that thinking is a process of reuse at multiple levels.

After Phrenology has a strong message aimed at neuroscientists. Anderson hopes that they will think deeply and carefully about the implications of the expectation of a one-to-one structure/function mapping, and also become aware of how these assumptions drive experimental design, data analysis, and conclusions, even when the assumptions are almost unconscious.

Anderson wants us to use the tools we have, like network analysis, to represent brain function in a more nuanced, complex way, which will hopefully lead to better science. In the book, he talks about some of the ways that the data that we already have can be used so that we are looking for more than just *where* or *what* questions.

So, as I look back on 2015, I realize that I didn't do as good a job as I usually try to of varying the technical level of the content of the show. Also, this was, as I have said, a difficult year. I did reuse a couple of older episodes, but I think those were good ones.

We started the year with talking with Dr. Evan Thompson about the importance of studying states of consciousness besides normal awakeness in order to have a better understanding of what the brain is doing and how the brain creates the sense of self. Thompson's focus was actually on considering how Eastern philosophy and Western neuroscience can inform and challenge one another.

Then, we talked with Dr. Norman Doidge about brain plasticity and, specifically, about some of the efforts to apply it in clinical settings.

One of the highlights of the year was Dr. Michael Gazzaniga, who is known as the father of cognitive neuroscience. We talked about his autobiography and learned a little bit about his personal experiences with working with the split-brain patients.

Then we did our Review Episode that involved a quick overview of neuroanatomy.

Dr. Edward Taub came back on the show to give us an update on constraint-induced movement therapy, or CI therapy. This was another episode about brain plasticity, and we learned that he is even working with spinal cord patients.

Then Dr. Bud Craig, who is best known for his work with the insula, came on and talked about the pathways that he has found in the brain that carry the interoception, or information from inside the body, to the brain. And we learned that primates and humans, in particular, have conscious access to more information than probably any other animal.

On a practical note, we talked with Fabrizio Benedetti about placebo effects and the evidence that what doctors say and how they act—and that's not just doctors; all people in medicine—is as powerful as any treatment that they use.

Dr. Anthony Chemero talked to us about phenomenology, which, although it is a

philosophical tradition, since it's about looking at experiences in and of themselves, it can help inform the embodied approach to neuroscience.

That led us to our final episode with Mike Anderson, where we talked about the neural reuse theory, which just is a way of making sense of the data that we have —the overwhelming data that we have—that shows that every part of the brain actually participates in multiple coalitions and functions.

So, I guess it wasn't that bad a year. I'm hoping that next year, we'll be able to cover more new material.

[music]

I usually finish up my annual review episode by reminding listeners of all the various resources that are available that complement listening to the podcast, such as the mobile app. However, this year, I'm only going to talk about one topic; and that actually is money. Because, as I mentioned on the most recent episode of *Books and Ideas*, this is the first time that I've ever been in a situation, since the death of my husband, that I actually need to make some money from creating my podcasts.

The Premium subscription for the *Brain Science* podcast was actually launched in January of 2014. And it has done okay. But I haven't really put much effort into promoting it; partly because shortly after I launched it, I decided to do a fellowship in palliative medicine.

Anyway, for those of you who aren't familiar with the Premium subscription, for $5.00 a month, you get access to the episodes released before 2013, as well as episode transcripts. If you want some of these episodes and you just want to purchase them individually, they are available for purchase on the website for $1.00 apiece.

I want to thank those of you who have signed up for the Premium subscription. But I've gotten a lot of comments from people who observed that, since they've been listening for a long time, they don't really need access to all these older episodes, but they'll sign up for the Premium subscription because they do want to support the show.

Prior to the Premium subscription, I had depended mostly on listener donations. And that was never very successful, because people just wouldn't remember to donate. Anyway, as I think I announced last month, I just started a Patreon account, and my intention for 2016 is to focus on fund-raising via the Patreon account. That's at patreon.com/docartemis.

Now, the difference about Patreon compared to, say, giving a donation with PayPal, is that the Patreon platform is really designed to encourage people to support creative works. So, there are a lot of other podcasters and other kinds of video-makers, and what not, using Patreon and having good success by also making it easy—with Patreon, it's easy to distribute extra content to your supporters.

So, if you sign up for Patreon, the first thing I'm going to do is I'm going to start distributing new episode transcripts to Patreon subscribers. Eventually there might be some other content, but for now, that's the only thing that I'm promising.

What if you're already signed up for Premium or you're already doing a donation? Well, I think that Patreon takes a smaller chunk out of the money than any of the other tools that I've had available in the past. With the Premium subscription, I make about half of that. It's going to be more than that, I think, with Patreon.

So, if you have the Premium subscription but you don't really use the Premium content or need the Premium content because you've already got all the old

episodes, then you might want to consider cancelling and moving on over to Patreon. If you use the Premium features a lot, then I would just stick with the Premium subscription.

If you are new to the show, my suggestion is to start out by getting the Premium subscription, so that you can get all the old episodes and download them. Get the transcripts, too, if you like transcripts. And then, when you get to the point where you don't really need that Premium content anymore, you can then convert your support over to Patreon.

The other advantage of Patreon is that you get to choose exactly how much support you want to give to the show, whether it's just $5.00 a month, or it's more, if that's what you can afford. You can make single donations or monthly commitments. It's totally up to you.

The main thing that you do need to know is that the success of this is going to have a lot of influence on whether or not this show continues past ten years. I am going to make a commitment to do ten years of the *Brain Science* podcast, but at the end of 2016, I'm really going to have to reevaluate where I am financially and whether or not it makes sense to continue.

But I guess I should remind you that, if you really can't afford to support the show financially, you can help by sharing the show with others. Word of mouth remains the most important way that people find the *Brain Science* podcast, other than searching. So, I hope that you will continue to share the show with others and to send me feedback at brainsciencepodcast@gmail.com.

Thanks again for listening. I look forward to talking with you again very soon.

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The new theme music for the *Brain Science* is "Mind Fire" by Tony Cotraccia. You can find his work at syncopationnow.com.

[music]

Transcribed by Lori Wolfson
All errors or omissions responsibility of the transcriber.