

# BRAIN SCIENCE PODCAST

*With Ginger Campbell, MD*

Episode #10: Neuroplasticity (first aired 4/17/07)

featuring [\*Train Your Mind, Change Your Brain: How a New Science Reveals Our Extraordinary Potential to Transform Ourselves\*](#) by Sharon Begley

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## INTRODUCTION

This is the *Brain Science Podcast* - the podcast for everyone who has a brain - and I'm your host, Dr. Ginger Campbell. On the *Brain Science Podcast* I explore how recent discoveries in neuroscience are unraveling the mysteries of how our brains make us who we are.

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This is Episode 10 of the *Brain Science Podcast*. In today's podcast I'm going to talk about neuroplasticity, which I think is an extremely exciting topic. But first I need to talk about a few personal notes.

I've been corresponding with some of you about the possibility of starting a Discussion Forum for the *Brain Science Podcast* and I've decided it's a good idea that I am going to implement. But I've done some research and realized that I need to have a truly hosted website so that I can have complete control over the forums. This means that I'm going to have to find a new web host and do some serious redesign of my website, so it's probably going to be a month or two before the forums become a reality.

Also, there's a contest starting with public radio for becoming a new NPR host and I'm planning to enter that contest, so I will be giving you more information on how you can vote for me. I will put that information at the end of the podcast and in the [Show Notes](#).

With regards to [Books and Ideas](#), I appreciate the support that I've gotten from most of you with regards to decreasing the frequency of *Books and Ideas*. I did put out a new episode a few days ago which is actually an [interview with Kirk McElhearn](#), who wrote to me about some of my comments on the *Brain Science Podcast*. So, if you don't already subscribe to the *Books and Ideas* podcast I hope you'll check that out. My goal is to put out *Books and Ideas* about once a month. I'll put it out more often if I happen to have more interviews to post.

Before we start talking about neuroplasticity I want to say something about today's book, which is called, [Train Your Mind, Change Your Brain](#), by Sharon Begley. If you've seen this book you might be at first a little nonplussed because it looks from the cover like something that you would see on *Oprah*. However, Begley is actually a very experienced science writer and this is an excellent book.

The basis of this book was a meeting between the Dalai Llama—who is the head of Tibetan Buddhism—and leading neuroscientists that occurred in India in 2004. The subject of the meeting was neuroplasticity, which is why I've chosen this book, because it provides a very excellent overview of the history of how neuroplasticity has been discovered in the last few decades, overturning a long-standing dogma that the brain was fixed.

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Until a few years ago the idea that the brain was fixed had been an unchallenged dogma for nearly 100 years. It was believed that the mammalian brain was fixed in two ways. First, it was believed that no new neurons could appear after birth,

and it was believed that the functions of the structures of the nervous system were permanently fixed. Both of these ideas have been disproven, and one of the key ideas of this book is showing how these ideas have been proven wrong.

A key premise of the book, *[Train Your Mind, Change Your Brain](#)*, is to show how this dogma is false, but even more surprisingly, to describe the scientific evidence that mental effort causes changes in the brain itself. I'm not going to list all the scientists that gave presentations that were described in this book, but I will have links for them in the [Show Notes](#).

I want to say something briefly about the relationship between Buddhism and science. The Dalai Llama is the spiritual head of Tibetan Buddhism, and his attitude is truly unique for a religious leader. Not only does he have a childlike curiosity about the world, but he believes that Tibetan Buddhism must incorporate the findings of science, and he's working to make modern science a part of the training of his monks. He sees this as essential to preserving Tibetan culture. He wants to keep Buddhism growing and developing by engaging with science.

Unlike most other major religions Buddhism lacks a central fixed dogma, so it's able to adapt and change with new cultures. The Dalai Llama knows that some parts of the Tibetan cosmology have been disproven by modern science. His own observations of the moon through a telescope as a young man disproved the myth that there's a rabbit in the moon. Doing this he was just following the example of the Buddha, who taught his followers to test what they were taught for themselves. The first conference between the Dalai Llama and scientists occurred in 1987. This book was based on the twelfth meeting which occurred in October of 2004.

The modern discovery of neuroplasticity was delayed somewhat by the assumption that it was impossible. Early on it was known that animal's brains

had different movement maps, but it was assumed that these differences were genetic rather than based on experience. In 1923 an experiment was done showing that these maps actually could change, but it was ignored. The first evidence that cortical areas of the brain in a primate could remap was done by Jon Kass and Michael Merzenich working with an owl monkey, where they showed that if one finger was denervated so it didn't send any signals to the brain, that part of the cortex would be taken over by other fingers.

This obviously was, as they wrote in 1983, contrary to the view of sensory systems as consisting of hard-wired machines. But they had a hard time getting their work published. Later they did an even more impressive study where they showed that if they taught the monkeys a really complex task the somatosensory cortex increased four-fold, which essentially proved that the somatosensory cortex was not hard-wired but could change with experience.

Then Rudolph Nudo, working with Merzenich at the University of California at San Francisco, devised an experiment where the monkeys had to get the food out of these little cups, and the smallest cup required that they learn how to do it with only one finger. And they were able to show that the part of the motor cortex needed doubled in size. This basically overturned the dogma that the adult brain can't change.

Their results were met with skepticism. There was also other primate evidence that sensory remapping would occur such that if an animal had a limb completely denervated that that area would take over another area, like getting sensation from the face. This is detailed in the book. I can't go into all of the details of this.

An experiment was done where the auditory nerve of the right ear in a ferret was prevented from reaching the thalamus—which is kind of the relay point for getting it to the sensory cortex—and what happened was the optic nerve sent a branch to the auditory cortex on that side. And they found that when light was

shined into that eye the animal responded as if it had heard the light: Again, another example of rewiring. A lot of experiments have been done showing that the cortex could not only change, but that it could change functions completely.

Now, a major obstacle to the acceptance of neuroplasticity was the long-standing dogma that the brain couldn't make any neurons after birth. The earliest evidence that new neurons appeared in the hippocampus was actually found in 1962, but it was ignored. The book goes through a great deal of details of the various experiments that were done up through the 80's that showed that there was evidence of neurogenesis in various types of animals, including primates.

Eventually the experimental methods improved to the point at which the objections to neurogenesis based on the model of the hard-wired brain had been disproven in three ways: 1. Fernando Nottenbaum had shown neurogenesis in the song areas of bird brains, and Elizabeth Gould of the Rockefeller Institute had shown neurogenesis in the hippocampus of rats and primates.

2. It was discovered that new neurons could arise from stem cells, even though mature neurons don't divide. This is really important because in most organs of the body the source of new cells is cell division. That's the reason why it was assumed the brain was so completely different, because no neuron division occurs in the brain. So, the discovery of the stem cells that could go on to become new neurons was very important, and is obviously the source of much research today.

3. Another important thing was discovering and proving that the new neurons could actually incorporate themselves into the functional architecture of the brain. It wouldn't matter if you had a new neuron if it didn't connect up anywhere. And this was proven, again, with the experiments of Nottenbaum and his song birds.

Now, once neurogenesis was accepted as a reality, obviously research shifted to trying to figure out how it occurs. But one of the obstacles is that there is still no non-invasive way of detecting new neurons in an active intact living brain. One study that was done that cannot be reproduced was a study with cancer patients in Sweden who were given a radioactive label called BRDU that marks the growth of new cells. They did this for the purpose of spotting cancer cells. They signed up five terminal patients, and after their deaths they found the BRDU label cells in the part of the hippocampus called the dentate gyrus.

These findings can't be reproduced because of the later concerns that this label might be toxic. But this is where the generally-quoted idea that this is where human brains make new neurons—that is, the dentate gyrus of the hippocampus—comes from. The same label has been given to rats, and it has been found that they will get more neurons when they are raised in a very enriched environment. And they will also, even as adults, get more neurons if they have an exercise wheel and they are able to voluntarily run in it. If they're forced to run they don't get new neurons; which is kind of interesting.

What is the possible significance of neurogenesis in the dentate gyrus of the human hippocampus? You may recall that the hippocampus is important for memory. But it turns out that this particular part of the hippocampus—the dentate gyrus—is shrunk to almost nothing in people who are depressed. So, that has some interesting implications that I hope I'll have time to come back to later.

At first it was assumed that whatever plasticity was available was something that could only happen in young brains. For example, it's known that if a child loses the entire left hemisphere before the age of four, he can still become almost normal and be able to speak, and read, and write. And those are functions that are normally part of the left hemisphere, so that implies the right hemisphere takes up the left hemisphere's functions.

But, as we've studied before, there are things that have to occur early on or they can't happen, such as the visual cortex must receive the proper visual inputs by no later than 11 months to get normal vision. And we know that the auditory cortex loses its ability to recognize new sounds, which is why it's hard to learn new languages without an accent after the age of about 10.

But Helen Neville of the University of Oregon, did some studies that show that the sensory cortex is not as fixed as you might think. She looked at deaf people, and it had been observed that they had better peripheral vision than normal. And what she found was that they had a larger area of visual cortex associated with motion, and they also had more activity in areas associated with multiple sensory inputs. So, this was the first demonstration that the brain changes in the deaf.

And it was also found that the auditory cortex was processing peripheral vision and motion. That's really the key thing. The auditory cortex—not just the enlargement of the visual cortex—but the fact that the auditory cortex wasn't just sitting there, it had been changed over to doing peripheral vision and motion. She also tested peripheral hearing in the blind and found that they did hear peripheral sounds better, and that these sounds were actually stimulating part of the visual cortex.

Another scientist, Mark Hallett at the NIH, showed some similar findings in blind people that are even more interesting. He showed that when a blind person learns how to read Braille there's an increase in the somatosensory cortex assigned mainly to the index finger—that's the one they usually feel the bumps with. It basically takes up some of the turf that normally belongs to the pinkie. And there were also changes in the motor cortex associated with the side-to-side motion—in other words, it became bigger.

He showed that this was not just a correlation, but actually causal, by a method called transcranial magnetic stimulation, which temporarily knocks out specific

regions. And they used this to show what a particular region does. So, what they found was, if they knocked out these particular regions then the person couldn't do the Braille.

Now, combine this with something that's even more interesting. In 1993 a Japanese scientist named Sadato joined Hallett's lab, and they used PET scans to show that the visual cortex is activated when a blind person reads Braille. This doesn't happen when a sighted person is reading Braille, or in a person who loses their sight later in life. This is only in someone who's been blind from early on. And then by using the transcranial magnetic stimulation they were able to show that if they knocked out the visual cortex they couldn't read Braille. So, the visual cortex was being used for reading Braille in a person who can't see.

It's also been shown by other researchers that blind volunteers have improved recall of words, and it appears that—and this is really very interesting also—when they're recalling words it's actually the visual cortex that's activated. Now, why is this important? It's important because it's not just a matter of, OK, the visual cortex went from one sensory function—say, to hearing instead of seeing, or to tactile—it's actually gone to something that's considered a higher level thing; a non-sensory thing. So, that's really significant. Blind people actually have better verbal memory and the left visual cortex is more active during this period.

The scientists that did these experiments also had them do an experiment where they listened to a noun and had to give a verb. And when they did this the visual cortex really lit up. But this didn't happen in sighted controls. So, this is showing that the visual cortex is able to take on a task as complex as language. And that was really a shock. It really supports the view of those who think that it's the connections that really matter.

But here's another interesting point. There was another study done with a blind painter who didn't know how to read Braille or anything. With him they showed

that his visual cortex lit up when he was drawing, but it was silent when he was doing verbal tasks like recall. So, it's not like the visual cortex is sitting there with some predetermined back-up plan for what it's going to do. It really does appear to be related to experience.

And in the book there's an explanation of how this has been used practically to develop a system for helping to treat dyslexia. It's called the Fast Forward™ Program. I'll put a link to that in the [Show Notes](#), since no doubt there might be a few of you who might know somebody who suffers from dyslexia.

But the conclusion is inescapable: Brain specialization is not a function of anatomy or dictated by genes, it's a result of experience. But a very important principle of plasticity, that I'm going to come back to over and over today, is that attention is important. If somebody is just stimulating your fingers, it's not going to give you the expanded cortex of a violinist.

The next issue is the question of whether or not neuroplasticity is just something that the young enjoy. I mean that would be interesting enough, but have limited applicability. However, it turns out that it's not just for the young. One thing that they did learn is that in terms of synapses and dendritic branches there's another burst of synaptic pruning in adolescents, and so you don't really have the adult-looking brain until 20 to 25.

So, that has some implications about what you do in your adolescence: Whether you're going to devote those years to developing neurons that are going to be devoted to video games, or some other skill that perhaps might have more long-term benefit. That's not to say that I have anything against video games. I think there is actually some evidence that certain kinds of video games have certain benefits. The point is, whatever you do during that period is going to stick with you, at least to a certain extent.

But back to the issue of what happens when you're an adult. We talked about how the visual cortex could do something in someone who had been blind since birth. So, if someone wanted to know, well what about someone who hasn't—because you don't see this change in people that become blind later on—they did an experiment where they blindfolded volunteers for a week and had them learn Braille.

What they found was that within a week they started to see changes in their visual cortex. It started to process auditory and tactile information, while the somatosensory cortex, that would normally process Braille in a sighted person, became quiet. And it happened in only about five days, which means that it's highly unlikely that they grew any new synapses. It's more likely that what was being unmasked was connections that just hadn't been being used. The fact that the adult brains gave the visual cortex a new job so quickly is a clue that perhaps neuroplasticity doesn't end in childhood.

Now, the downside of neuroplasticity—I guess if you want to call it a downside—is that if someone, say they've been deaf since birth and they get a cochlear implant, it doesn't really work very well because the auditory cortex has already been reassigned. It's not just sitting there waiting to get hearing. And the same thing with vision. They found that to give people visual prostheses, what really works is to give them something that will give them tactile or auditory inputs, because that's what the visual cortex has kind of developed into being able to do.

So, it's actually been found that giving somebody some kind of—like for example, a camera that gives them tactile input to their fingers—they can learn to use that to see. That always seemed really weird to me, but now it makes sense in light of the fact that we now know that the visual cortex has kind of been reassigned to tactile and auditory inputs. And since cortex gets reassigned—it doesn't just sit there doing nothing—that may be part of the reason why people have phantom limb pain. It's not uncommon for a person who's had a limb amputated to have

an experience of somebody touches their face and they feel like they touched the missing limb.

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A very important implication of the fact that neuroplasticity is possible in adults is the fact that stroke may not be forever. One of the most exciting experiments described in this book is the work of Edward Taub, who actually is now at the University of Alabama at Birmingham, which is right down the street from me. It's the place where I went to medical school. He originally worked with the Silver Spring monkeys, but he wondered about whether or not these findings could be applied to people with adult brain injuries like strokes, and he thought that perhaps some of the disability of stroke was from what he called learned disuse.

So, he developed a treatment called constraint-induced movement therapy. And basically what this is, is that the person is prevented from using their good limb. They are trained extensively for several hours a day on using the limb that has been paralyzed by their stroke. And he was able to show improvement within 10 days in people who were chronic—that is, they were more than a year out from their stroke—which means that the improvement wasn't just spontaneous recovery.

For awhile he continued to have NIH funding problems, but in 2006 he published a rigorous study involving 41 patients that were an average of 4½ years out. 21 got the treatment, 21 were controls, and they trained for 6 hours a day for 10 days. They showed significant improvement after 2 weeks, and the improvement persisted for 2 years. It looks like what's happening is that nearby neurons are being recruited, but the exact mechanism is not determined yet.

One problem with constraint-induced therapy is that it is very time-intensive. However, he has developed a program that people can do as an outpatient, and if you want to you can Google AutoCITE and find several references to it on the Internet.

Taub hasn't restricted his research to just stroke. He also was involved in the research that showed that when people play the violin, that part of the brain that goes to the fingers of the left hand increases in size. But here's the part that I think might be surprising, and that is that they showed that these increases occur even in people who don't learn how to play the violin until they're an adult. Now, not to the same extent, but they do improve. There's actually a lot of potential for using these principles for clinical applications, and I think that this is a field that really deserves much more attention. But one important thing, again, is that the key constraint is attention.

So far we have considered motor cortex and sensory cortex, but let's talk about some things that are really considered a little bit more higher-level. And the findings might really surprise you. I'm going to talk about two examples. One is the treatment of obsessive-compulsive disease and the other is the treatment of depression.

In obsessive-compulsive disease, a person first of all is plagued by obsessive thoughts to do something like wash, or lock the door, or whatever, and also they're plagued by a sense that something is wrong. And that's really very important. And it's been shown that this seems to involve hyperactivity of the orbital frontal cortex and an area called the striatum. These guys get signals from the amygdala, which is the lower emotional part of the limbic system, so they seem to constitute something of what you might call the worry circuit.

Now, most people that have obsessive-compulsive disease know that their thoughts aren't valid, and they have kind of a sensation of, 'It's just not really me.'

So, neuropsychiatrist Jeffrey Schwartz at UCLA is the one that has successfully treated obsessive-compulsive disease with a form of meditation treatment. And basically the fact that they sort of recognize the thoughts aren't right was the basis of his treatment.

Antidepressants can help some patients, but back in the 80's the main form of treatment was called exposure and response prevention, which was a pretty cruel treatment. It consisted of doing things like making a person go in the bathroom and touch nasty stuff, and then not allow them to wash their hands. One of Schwartz's motivations for developing his treatment was to get away from that treatment.

So, he used group therapy and he taught a group of patients basic mindfulness meditation, with two goals. One was to experience their symptoms without reacting to them. And that's a really basic aspect of mindfulness meditation. You allow whatever thoughts or feelings you have to come up and you don't do anything, you just watch them and try to let them go.

And secondly he wanted them to realize that the feeling that something was wrong was just a wiring defect. In other words, to relabel what it is in their minds. So, they were learning to see that their obsessive-compulsive disease was not them, just a brain malfunction.

They had a surprisingly good response to the treatment. And the PET scans—which show activity in the brain—showed that the activity of the orbital frontal cortex and striatum fell significantly. This was evidence, basically, that mindfulness meditation was able to change the brain.

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Now, let's consider depression, because it's even more common. And I spoke briefly on my last podcast about some of the limitations of looking at depression

as being just about a neurotransmitter deficit. It's well established that cognitive behavior therapy is just as effective for mild-to-moderate depression as drugs. But what's really interesting is how it works. It turns out that it's really a form of mental training, because basically what they do is the patient is taught to not allow thoughts that normally would spiral into depression to take hold.

For example, a normal person when they have a setback says, 'Oh, well, tomorrow will be another day.' Whereas a person who is prone to depression might have a setback and say, 'My life is never going to be any better,' or, 'Things are hopeless.' Cognitive behavior therapy teaches people to react differently.

There are some interesting differences between the response of the brain to cognitive behavior therapy and its response to drugs. It's actually been shown that the brain responds differently to the two treatments. Cognitive therapy actually mutes what has been found to be an overactivity of the frontal cortex—that part of the brain that kind of just ruminates and goes around and around until you get deep into a hole. In contrast the drugs, like Paxil, actually raise the activity there and mute the activity of the limbic system.

Studies have been done to see what is the difference between how cognitive behavior therapy and antidepressants affect the brain, and it's interesting to note that they have almost opposite effects. Cognitive behavior therapy mutes the overactivity of the frontal cortex and increases the activity of the hippocampus in the limbic system—the brain's emotional system. Drugs like Paxil and Prozac have the opposite effect. They actually make the frontal cortex more active and they mute the limbic system. So, this means that cognitive behavior therapy is a top-down approach, whereas the drugs are kind of bottom-up.

Probably the area where this has the most practical significance is in terms of relapse, because people who are on drugs usually end up having to take the drugs for a prolonged period of time, whereas people who have cognitive behavior

therapy have been shown to have significantly less relapse. And this has been shown on several different studies that involved people who had a history of several severe relapses. So, you might wonder why cognitive therapy isn't used more often if even mainstream medicine recognizes its effectiveness.

There are several obstacles to the more widespread use of cognitive behavior therapy. One obvious one is probably there are not that many people who know how to do it correctly. And this relates to the fact that, as you probably know, the insurance companies would rather pay for drugs than things that they label as mental health services. Most insurance companies will only reimburse you for about 50% of the cost of seeing somebody that does something like cognitive behavior therapy, and they'll put a strict limit on the number of visits. Whereas they'll pay for you to take a drug indefinitely. It's kind of ironic, but that's part of the way our system is currently constructed.

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There is also considerable discussion in this book about behavior with regards to problems with emotional attachment, and empathy, and these kinds of behaviors that tend to be regarded as somewhat fixed after childhood. And you wouldn't be surprised to know that it has been shown that meditation and similar practices can change this behavior to a more compassionate direction. Actually that's kind of the point of certain kinds of Buddhist meditation. But I can't get into this because I've already gone way past my reasonable length, as usual.

I want to summarize the main ideas. First is that neuroplasticity is a reality. Our brains can change. This is not something that we lose after we grow up, although our capacity for it is obviously more limited. Various parts of the brain have been shown to have the ability to take up tasks that are completely unlike what they were originally assumed to be destined for. And this is very surprising, and suggests that the genetic control is not as tight as some have assumed.

A key part of neuroplasticity is the role of attention. And probably one reason why we don't see more practical everyday examples of neuroplasticity is because it doesn't just happen; it requires mental effort. So, as an adult in order to learn a new skill it does require more effort than it probably did when we were younger, and it is easy to jump to the conclusion that we just can't learn new stuff. But the evidence is that that's not true. If you want to improve your brain's neuroplasticity it appears that practices such as mindfulness meditation would help you to improve the attentional aspect and therefore perhaps improve your ability to acquire other new abilities.

In closing, this is what Dr. Richard J. Davidson said to the Dalai Llama. Dr. Davidson had been studying the monks for several years, observing how their brains were clearly changing with years of meditation. And this is what he said. "Neuroplasticity will be a counterweight to the deterministic view that genes have behavior on a very short leash. The message I take away from my work is that I have a choice in how I react, and who I am depends on the choices I make, and that who I am is therefore my responsibility." This is on page 242.

So, in this book we learn that mental attention and effort can change the brain, and this is an objective scientific fact. To me this seems to argue against the view that free will is an illusion, even if we can't quite explain exactly how this happens. I'm not ready to go to looking for a dualistic non-material mind explanation. One theory that has been proposed by a scientist named Gerald Edelman is the idea that some of these functions are the result of the feedback loops between various parts of the brain.

And then there is the idea of emergence, which was proposed by Roger Sperry in a form called emergent materialism, which ironically usually gets attacked from both sides. Those who want to reject dualism completely tend to regard this as a dualistic point of view, and then the pure dualists say that he's still a materialist.

I don't know what the answer is. These new findings do show that there is more going on than we might have expected. And I think that neuroplasticity is a really exciting field. I'm looking forward to seeing what else we're going to discover about this in the next few years.

I think it's really exciting to realize that while it might be harder to learn new things than it was when we were younger, we can do so. And I'm excited to know that there's hope for patients who have strokes and other diseases that involve brain damage and might be treated by teaching other parts of their brains to take up the functions.

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So, that was this episode of the *Brain Science Podcast*. I may have gotten a little carried away because neuroplasticity is really a subject that I could probably just talk about for hours. And I left out a lot of the details of the various experiments, so if you're into that sort of thing I really recommend this book. I will have a link to it on the [Show Notes](#), and I also will try to provide links to the various scientists—as many as I can find. As usual, I would love for you to give me feedback by posting comments at [brainsciencepodcast.com](http://brainsciencepodcast.com), or sending me email at [docartemis@gmail.com](mailto:docartemis@gmail.com).

Now, I mentioned at the opening that there's going to be a contest for getting a job as a host at NPR. The name of the contest is called Public Radio Talent Quest, and I think it's at [publicradioquest.com](http://publicradioquest.com). And if you want to vote for me and you're on that site, I'm listed as Doc Artemis. I haven't put up my little two-minute blurb yet, but I should have that up in the next couple of weeks. (note: this contest was concluded in the summer of 2007.)

Also, I should be putting a badge on my website. Their website says that every time somebody clicks on one of those badges it gets you a vote. I don't really

know how important the voting is. They've also got NPR judges that are real NPR people, so I really don't have a clue whether you have to have a lot of votes—if it's an American Idol thing—or whether actual talent is what you need. But, if you've got time to check it out and vote for me, I appreciate it.

And, don't forget that there is a new episode of *Books and Ideas* up. I'll be back with you in a couple of weeks. The next podcast, I think, is going to be about emotion. See you then.

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