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FIVE LIFE-ENHANCING INSIGHTS FROM NEUROSCIENCE

by Michael W. Taft

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Introduction
My friends at Sounds True, knowing my passion for neuroscience and the inner life, asked me to help them to sift through the massive amount of research and studies and share with you five practical insights that can radically improve the way you live your life.

We have learned more about our brains in the last 15 years than we learned in all our previous history. We used to believe that the secrets of the human brain were non-physical and inaccessible—part of the intangible realm of the soul and mind. Now we can reach out and touch the physical reality of these secrets, but the research retains the aura of this long-held belief. It seems like we are using our fMRI and EEG machines to uncover something precious and even sacred about ourselves, as if we could hold out a yardstick and measure a dream.

It is indescribably and irresistibly wonderful to discover your own deepest inner workings. In that sense, neuroscience is related to the spiritual quest or the philosophical search for self-understanding. It is a realization of the Oracle at Delphi's injunction to "Know Thyself." That's what made me and so many others excited about the field of neuroscience in the late 1990s, and what still turns me on about it today.

The moment I make this statement, it is followed by the reasonable request for an example.

I won't give you just one but five recent examples of the most interesting and practical discoveries made by neuroscience about the human brain.

It's important to realize that the field is still new and still in the process of revelation. It's possible some of these insights might end up being changed or replaced. However, hopefully the five topics I briefly cover here will have the desired effect: to ignite in you a fascination with the discoveries of neuroscience deep within the folds of your own unique, surprising, and miraculous human brain.

Neuroplasticity—The Brain's Surprising Ability to Change Itself
The artist M.C. Escher's famous lithograph entitled "Drawing Hands" depicts two hands rising out of the flatness of paper into plump, real three-dimensionality using pencils to draw each other into existence. This paradox of self-creation is an apt metaphor for our first topic: neuroplasticity. Neuroplasticity is the brain's almost shocking ability to transform itself physically into whatever shape it desires. One of the very first

discoveries of the new science of the brain, it remains the most important and fascinating of them all. In it lies the truth that we as human beings are not stuck with the cards we were dealt by genetics or circumstance, but in fact can change to become more the people we dream ourselves to be.

Previous to the discovery of neuroplasticity, the scientific consensus was that the structure and function of the human brain was changeable (i.e. “plastic”) in childhood, but became fixed or static in adulthood. If an area of the brain was damaged, science believed it was impossible to ever recover the capacities for which that area was responsible. If a brain injury caused you to become blind, then there was no hope of recovery from that blindness. The concept that “brain cells can’t regrow” was so well known there was even an urban myth that “three beers kill 10,000 brain cells, and they never grow back.”[1]

The breakthrough experiments in neuroplasticity were performed by Paul Bach-y-Rita of the University of Wisconsin in the 1960s. Bach-y-Rita created a special device that consisted of a camera that transformed its input into electrical signals. These signals were then sent to a panel of 400 vibrating metal plates set in a grid. Subjects who were blind from birth sat in a chair with the plates touching their back and felt the image—in the form of vibrating “dots” on their skin—of whatever the camera was looking at. Eventually, these patients could distinguish faces from other images, which Bach-y-Rita claimed was proof that they were processing the skin vibrations using their visual cortex. They were “seeing” with their skin, because their brain had changed the way it was interpreting the input from their skin. In an epic case of rewiring the brain, one physical sense had been substituted for another.

In a later experiment, Bach-y-Rita created a special device on the tongue that allowed a person whose vestibular system had been damaged to regain their sense of balance. The explanation for all these phenomena was that the brain had reorganized itself to interpret the new information, which was the first major evidence of neuroplasticity. For the first time it was clear that an adult brain wasn’t “static,” but could fundamentally change.

Since then, many experiments have shown the adult human brain to be capable of massive rewiring, sometimes occurring very quickly in response to trauma.

But brain plasticity is good news even to those of us with no brain damage at all. Take the famous case of the London taxi drivers. London is an ancient city, and to

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[1] Matt Soniak. “Does Drinking Alcohol Kill Brain Cells?” *Mental Floss.* August 1, 2015. http://mentalfloss.com/article/49024/does-drinking-alcohol-kill-brain-cells

successfully find your way through its 25,000 winding and disordered streets is a prodigious feat of memory (or was previous to satellite navigation devices). In order to pass their licensure exam, London cabbies were required to demonstrate that they had learned the map of London—similar to memorizing a bowl of spaghetti—by heart.

In the 1990s, Irish neuroscientist Eleanor Maguire of University College in London was studying the area of the brain known as the hippocampus, which is responsible for spatial memory. Maguire noticed that animals that navigate a lot have much larger hippocampi than those who do not, and wondered if something similar applied to humans.[2] So, she measured the gray matter of London cabbies before and after they studied for their licensure exams and found that the hippocampi of the taxi drivers had grown significantly in the process. Their brains had "bulked up" in the area where more memory power was required—almost like a weightlifter gaining muscle mass in the limbs they are exercising.

The almost shocking implication is that adult human beings have brains that are surprisingly nimble and adaptable. The brain can not only rewire its existing circuits to adapt to a new situation, it can even grow *new* circuits to enhance its abilities. This neuroplasticity helps to explain, for example, how practices like meditation can be used over a period of time to change the way the brain—and therefore the person—responds to the challenges of life. Neuroplasticity means that, like the "Drawing Hands" image, we can decide who we want to become—and then, with enough practice, to become that person in reality.

One of the most interesting applications of this ability comes in the area of personal outlook or disposition. Science has known for a while that optimists enjoy many concrete and important advantages in life, such as increased pain tolerance[3] and diminished sense of loneliness.[4] What we're coming to realize is that, far from being a permanent character trait, dispositions like being an optimist or pessimist can be cultivated on purpose. That is: you can learn to be an optimist and enjoy the same benefits as a person who is naturally that way. How? Simply by training yourself to look for things that are going right, rather than focusing on things that are going wrong. Due to brain plasticity, you can greatly improve your ability to notice the positive over time.

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[2] *The Naked Scientists.* December 12, 2011. http://www.thenakedscientists.com/articles/interviews/navigating-taxi-drivers-brain

[3] Burel R. Goodin, Tarek Kronfli, Christopher D. King, Toni L. Glover, Kimberly Sibille, Roger B. Fillingim. "Testing the relation between dispositional optimism and conditioned pain modulation: does ethnicity matter?" *Journal of Behavioral Medicine* 36:165 (2012). doi:10.1007/s10865-012-9411-7

[4] Nathaly Rius-Ottenheim, Daan Kromhout, Roos C. van der Mast, Frans G. Zitman, Johanna M. Geleijnse, Erik J. Giltay. "Dispositional optimism and loneliness in older men." *International Journal of Geriatric Psychiatry* 27:2 (2012). doi:10.1002/gps.2701

Anxiety and the Amygdala

Feeling stressed out? Most of us are, and—as if you needed to add anxiety to your list—the stress we are experiencing is literally killing us. Stress is a contributing factor in heart disease, diabetes, asthma, Alzheimer's, obesity, and a whole host of other illnesses that are doing us in. Given the unpleasant and truly dangerous nature of stress, wouldn't it be awesome if there were some way—short of quitting your job and moving to the mountains—to reduce its negative effects?

Well, there is at least one way: mindfulness meditation. This meditation practice uses the power of neuroplasticity to literally reduce the ability of the brain to experience stress.

The key to this minor miracle is a little area of the brain known as the amygdala. The amygdala is the beating heart at the core of the "fight-or-flight" response—a tripwire for anything fearful or stressful. Absolutely crucial for survival, the amygdala lets you know when it's time to get out of a dangerous situation, like NOW. But in our high-speed, always-on, constant-stimuli society, the amygdala is out of its depth. It didn't evolve in an environment with so much intensity—24-hour cable and smartphone alerts—and is therefore chronically overstimulated and hyperactive, as if it's constantly ringing the alarm bells in our head. Hence the stress.

But if you think about it from the perspective of the new brain science, the amygdala is simply a bundle of neurons located in the temporal lobe. (You actually have two amygdalae and two temporal lobes in your brain.) We've seen that neuroplasticity can increase the size of a brain area associated with something that you'd like to increase, but can it do the opposite thing for something you rather experience less? Furthermore, is it possible to have this decreased anxiety not just be something you experience while meditating, but actually available as an ongoing trait?

The answer is in the research. One study conducted by scientists at the University of Pittsburgh looked at 155 people for their mindfulness traits using a standardized test. They then measured the volume of their amygdalae, and found that the size of the amygdalae was negatively related to the level of mindfulness.[5] So, people with a small amygdala appear to be much more mindful—but do we know that meditation causes this, and isn't just correlated?

[5] Adrienne A. Taren, J. David Creswell, Peter J. Gianaros. "Dispositional Mindfulness Co-Varies with Smaller Amygdala and Caudate Volumes in Community Adults." *PLOS ONE* (2013). doi:10.1371/journal.pone.0064574

Sara Lazar of Harvard did before and after studies[6] of 16 people participating in an eight-week mindfulness meditation course for the first time, compared to controls who did no meditation. They practiced an average of 27 minutes per day and reported decreases in feelings of stress over that time. When Lazar measured the brain cell volume of the amygdala at the end of the course, it had significantly decreased in size—an outcome that correlated with the subjects' self-reported experience. There were also increases in the hippocampus and frontal cortex—areas that are associated with emotion regulation and self-referential processing. As Lazar put it, "This study demonstrates that changes in brain structure may underlie some of [the] reported improvements and that people are not just feeling better because they are spending time relaxing." Lazar even conducted a follow-up study that showed that the feelings of reduced stress lasted over time, suggesting changes to the amygdala were long term, producing personal traits and not just passing moods.

We can do the same intervention that Lazar had her study participants do—basic mindfulness practices. One of these is mindfulness of breathing, which simply consists of sitting quietly and feeling yourself breathe. You don't change or control your breathing, and you're not trying to make anything special happen. Instead, you're just feeling the sensations of breathing, such as your belly rising and falling, your chest expanding and contracting, the feeling of air rushing in and out of your nose. To help you stay present with these sensations, you can think, "Breathing in, breathing out," which meditators call "labelling."

It is one of the wonders of the new neuroscience that many of these ancient practices, used by hundreds of generations of meditation practitioners, are being proven to have powerful, measurable effects. They aren't just mystical placebos; they can and do really help us overcome the suffering of anxiety.

Oxytocin—Give Me a Hug

The main hormone involved in anxiety and stress is cortisol, one of the chemicals released into the body when the "fight-or-flight" mechanism kicks in. Cortisol causes your heart rate to increase, your breathing to speed up, your blood to shunt towards the big muscles in your arms and legs (making it easier to run or fight), and a whole host of other changes, all meant to save your life in an emergency. It's great for survival in the short run ("Watch out for that truck!"), but it's terribly unhealthy when it goes on and on. If you're stressed out every day as most of us are, instead of saving your life, cortisol can make illnesses and diseases more likely to arise or to become worse. With stress

[6] Britta K. Hölzel, James Carmody, Mark Vangel, Christina Congleton, Sita M. Yerramsetti, Tim Gard, Sara W. Lazar. *Psychiatry Research* 19:1 (2011). "Mindfulness practice leads to increases in regional brain gray matter density." doi:10.1016/j.pscychresns.2010.08.006

as a major contributing cause of death in our society, figuring out how to reduce it can be a matter of life and death.

There used to be a lot of talk about the "relaxation response" being the cure for stress. Somewhat amusingly, the relaxation response is the system simply returning to its normal state after the cortisol is broken down. The better question is whether there is an evolutionary response that can reverse or overcome stress, and if so, how do we trigger it?

There is. It is called the "tend-and-befriend" behavior.

Tend-and-befriend (explicitly named to mirror fight-or-flight) is a completely different—and quite fascinating—response to stress. It was first described by Shelly Taylor of UCLA in 2000, and it offers an utterly new understanding of how human beings (especially women) evolved to handle challenges. Simply put, in the face of a dangerous stressor, a group of humans can band together and support each other. Rather than running from an attacker or trying to fight it individually (which is seen as a more typically male behavior), it's possible to join forces, metaphorically circle the wagons, and face the problem as a group.

And just as the fight-or-flight mechanism has its own hormone to trigger it, the tend-and-befriend behavior, too, has a hormone underlying it—oxytocin, a hormone that has become something of a chemical celebrity in the new millennium. Often called the "love drug," oxytocin was first discovered as the hormone that caused the uterine contractions in a birthing mother as well as causing breast milk to flow postpartum. But it's about far more than mother-love; it's also released when we cuddle each other, and it increases trust,[7] empathy,[8] generosity,[9] and promotes social bonding. Mice who were genetically engineered to lack oxytocin treated mice they had met before like strangers.[10] Humans

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[7] Angeliki Theodoridou, Angela C. Rowe, Ian S. Penton-Voak, Peter J. Rogers. "Oxytocin and social perception: Oxytocin increases perceived facial trustworthiness and attractiveness." *Hormones and Behavior* 56:1 (2009). doi:10.1016/j.yhbeh.2009.03.019.

[8] René Hurlemann, Alexandra Patin, Oezguer A. Onur, Michael X. Cohen, Tobias Baumgartner, Sarah Metzler, Isabel Dziobek, Juergen Gallinat, Michael Wagner, Wolfgang Maier, Keith M. Kendrick "Oxytocin enhances amygdala-dependent, socially reinforced learning and emotional empathy in humans." *The Journal of Neuroscience.* 30:14 (2010). 4999–5007.

[9] Paul J. Zak, Angela A. Stanton, Sheila Ahmadi. . "Oxytocin Increases Generosity in Humans." *PLOS ONE*:. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0001128.

[10] Jacqueline N. Crawley, Thomas Chen, Amit Puri, Richard Washburn, Timothy L. Sullivan, Joanna M. Hill, Nancy B. Young, Jessica J. Nadler, Sheryl S. Moy, Larry J. Young, Heather K. Caldwell, W. Scott Young. "Social approach behaviors in oxytocin knockout mice: Comparison of two independent lines tested in different laboratory environments." *Neuropeptides* 41:3 (2007). doi: 10.1016/j.npep.2007.02.002.

who received a dose of oxytocin spray in their nose (the common method used in many studies) showed increased memory for social information[11] and the faces of others.[12] Oxytocin is released during sexual intercourse and orgasm,[13] helps couples bond,[14] and even functions to keep males faithful in monogamous relationships.[15] If you want to have satisfying social, parental, and sexual relationships—all important factors in overall well-being—oxytocin would seem to play a key role.

On top of all of these qualities, however, oxytocin is the magic bullet for down-regulating the HPA[16] (axis of the fight-or-flight mechanism). It inhibits the amygdala[17] (thereby reducing fear), suppresses cortisol,[18] and increases feelings of calm and contentment. So, oxytocin helps you to chill out and let go of stress and anxiety. There's even evidence that oxytocin reduces inflammation factors in the blood, which promotes the

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[11] Adam J. Guastella, Philip B. Mitchell, Frosso Mathews. "Oxytocin Enhances the Encoding of Positive Social Memories in Humans." *Biological Psychiatry* 64:3 (2008). doi:10.1016/j.biopsych.2008.02.008.

[12] Ulrike Rimmele, Karin Hediger, Markus Heinrichs, Peter Klaver. "Oxytocin Makes a Face in Memory Familiar." *The Journal of Neuroscience* 29:1 (2009). doi:10.1523/JNEUROSCI.4260-08.2009.

[13] Marie S. Carmichael, Richard Humbert, Jean Dixen, Glenn Palmisano, Walter Greenleaf, Julian M. Davidson. "Plasma oxytocin increases in the human sexual response." *The Journal of Clinical Endocrinology and Metabolism* 64:1 (1987). doi:10.1210/jcem-64-1-27.

[14] Donatella Marazziti, Bernardo Dell'Osso, Stefano Baroni, Francesco Mungai, Mario Catena, Paola Rucci, Francesco Albanese, Gino Giannaccini, Laura Betti, Laura Fabbrini, Paola Italiani, Alessandro Del Debbio, Antonio Lucacchini, Liliana Dell'Osso . "A relationship between oxytocin and anxiety of romantic attachment." *Clinical Practice and Epidemiology in Mental Health* 2 (2006). doi:10.1186/1745-0179-2-28

[15] Dirk Scheele, Nadine Striepens, Onur Güntürkün, Sandra Deutschländer, Wolfgang Maier, Keith M. Kendrick, René Hurlemann. "Oxytocin Modulates Social Distance Between Males and Females."*The Journal of Neuroscience* 32:46 (2012). doi:10.1523/JNEUROSCI.2755-12.2012.

[16] WalentyHartwig. *Endokrynologia praktyczna* (Warsaw: Państwowy Zakład Wydawnictw Lekarskich, 1989). .

[17] Daniele Viviani, Alexandre Charlet, Erwin van den Burg, Camille Robinet1, Nicolas Hurni, Marios Abatis, Fulvio Magara, Ron Stoop. "Oxytocin Selectively Gates Fear Responses Through Distinct Outputs from the Central Amygdala." *Science* 608:6038 (2011). doi:10.1126/science.1201043 .

[18] Markus Heinrichs, Thomas Baumgartner, Clemens Kirschbaum, Ulrike Ehlert. "Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress." *Biological Psychiatry* 54:12 (2003). doi: 10.1016/S0006-3223(03)00465-7.

speedy healing of wounds.[19] Does this mean that when mommy "kisses it" it really does "make it better?"

As of this writing, there is no direct evidence that visualization increases oxytocin. However, there are reasons to believe that it can. For one, just watching a short, emotionally stimulating movie can raise oxytocin levels as much as 47 percent.[20] It seems like the brain doesn't distinguish carefully between empathy for an actual human and empathy for an image or fantasy of a human being. Thus, when we just imagine feeling close to other people, it's likely that the same mechanism kicks in and increases oxytocin.[21]

Try this short visualization: Imagine that you are hugging somebody you truly love. See yourself wrapping them in the biggest, most loving, joyous hug you can imagine. The two of you are feeling love, connection, joy, caring, and comfort. As you see this in your mind's eye, try to *feel* it in your body too. Oxytocin is the chemical that gives us the "warm fuzzies," so tune in during that sensation.

Human beings are exquisitely tuned by evolution to care for each other. Not only does the care we give help others, but it also directly helps ourselves. When we care about healing others, it heals us. When we want others to feel better, we feel better too. Encouraging others to feel safe and calm encourages us to feel safe and calm. Simple acts of kindness, of caring, of giving people a hug leverages this built-in tend-and-befriend feedback to boost your resilience—and your oxytocin—to higher and higher levels. And it feels great.

Present Moment Happiness

Remember when computer monitors needed screensavers? A screensaver was a graphics program that activated when your computer was turned on, but not being used. The purpose of the screensaver was to keep the monitor pixels from burning out, which would happen if the monitor was left on without changing images for days. It turns out that a computer that's left on, but is not being actively used, can still be doing quite a bit of processing if you give it something to do in its downtime.

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[19] Jean-Philippe Gouin, C. Sue Carter, Hossein Pournajafi-Nazarloo, Ronald Glaser, William B. Malarkey, Timothy J. Loving, Jeffrey Stowell, Janice K. Kiecolt-Glaser. "Marital behavior, oxytocin, vasopressin, and wound healing." *Psychoneuroendocrinology* 54:12 (2003). doi: 10.1016/S0006-3223(03)00465-7.

[20] Jorge A. Barraza, Paul J. Zak. "Empathy Toward Strangers Triggers Oxytocin Release and Subsequent Generosity." *Annals of the New York Academy of Sciences* 1167 (2009). doi:10.1111/j.1749-6632.2009.04504.x. .

[21] Rick Hanson. "The Evolution of Love." http://www.psychology.com/articles/?p=198.

Some of the most exciting current neuroscience looks into the question of what the brain does when it's not involved in any particular task—when it is in "screensaver mode." There are colloquial terms for this state of mind, like "daydreaming" or being "checked out," but in neuroscience it's called "mind wandering." Through the use of fMRI, scientists have discovered that there is a specific brain network dedicated to this mode of processing. And in a fascinating experiment,[22] they found something surprising: *most of us are checked out half of the time*.

In a fascinating experiment, Harvard scientists Matthew Killingsworth and Daniel Gilbert created an iPhone app that sent participants messages at random intervals a few times a day. The messages prompted users to answer an online survey which asked (1) what they were doing (they could choose from a list of about 20 items), (2) whether they were thinking about that activity or about something else, and (3) how they were feeling emotionally (on a scale of 0–100). Over 5,000 individuals participated, and the response rate was quite high, with people answering the messages over 80 percent of the time. After correcting for a number of factors that might have skewed the data, Killingsworth and Gilbert had records for 2,250 adults to analyze.

They discovered that people's minds are wandering an amazing *47 percent of the time*. That's right: people are daydreaming—thinking about something completely unrelated—about half the time, no matter what activity they were involved in. (Except sex, when it was wandering "only" 30 percent of the time. But, then again, these people chose to answer their iPhone during sex.) The data revealed something important to us in terms of well-being: people were on average *least happy during mind wandering*, and this was true no matter what activity they were doing. Hence the title of Killingsworth and Gilbert's article, "A Wandering Mind Is an Unhappy Mind."

So, daydreaming tends to bum you out, and paying attention to the present moment tends to make you feel good. You might actually feel better concentrating on an unpleasant present moment than daydreaming about having sex with your favorite fantasy person. The Harvard experiment lends weight to the likely effectiveness of mindfulness meditation in improving well-being, since mindfulness meditation teaches you to stay focused on the present moment. And there is solid research[23] to demonstrate that meditation—by keeping your attention centered in the present moment—reduces your mind wandering. I've heard many meditation teachers over the years say that even having a hard, emotionally fraught meditation session was better than not meditating at all. I always wondered if that was just a platitude to help students

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[22] Matthew A. Killingsworth, Daniel T. Gilbert. "A Wandering Mind Is an Unhappy Mind." Science 330:6006 (2010). doi:10.1126/science.1192439.

[23] Judson A. Brewer, Patrick D. Worhunsky, Jeremy R. Gray, Yi-Yuan Tang, Jochen Weber, and Hedy Kober. "Meditation experience is associated with differences in default mode network activity and connectivity." *Proceedings of the National Academy of Sciences of the United States of America* 108:50 (2011). doi: 10.1073/pnas.1112029108.

make it through a chewing-on-rocks type of sit, but this study (and others) would suggest their advice was right on target.

Scientists have discovered that there is a brain network associated with mind wandering, and have named it the *default mode network* (DMN), since mind wandering seems to be our default setting. We experience it subjectively as a stream of memories, plans, and fantasies, mostly centered on our personal concerns and ourselves. A soundtrack of it might go something like, "I shouldn't have said that to her last night. So stupid. That reminds me of a date I had in high school, when I took my girlfriend out in Dad's Jeep. I've always wanted to buy a new Jeep like that. Blue. First I'll have to get a better job…" and so on, ad nauseum. Often these words are accompanied by internal images as well. Mental pictures of the date, of the Jeep, of Dad, and so forth.

So, the default mode is like a never-ending reality TV show starring ourselves, in which we ruminate on things that happened in the past and things which may happen in the future. To describe it generously, we might say that the default mode network is concerned with evaluating the outcomes of past actions and using that as a basis for planning future actions. In fact, such evaluation and planning is probably the "intended" function of the default mode network in the brain.

More often, however, it's the mode in which we beat ourselves up over events from the distant past we can't change, and worry ourselves sick about future events that will never occur. In the words of a snarky remark of unknown origin—though often attributed to Mark Twain—"I've had a lot of worries in my life, most of which never happened." This serves as a perfect description of DMN activity. For most of us, the DMN is the nexus of negative, self-referential anxiety and depression.

Default mode network activity is roughly the opposite of a flow state. In a flow state, you begin to lose your sense of self in a task; most DMN thought is self-referential. A flow state is intrinsically rewarding and serene, whereas mind wandering typically leaves you feeling bad. The essence of a flow state is concentrated activity; the DMN turns on when you are not focused on any activity. In fact, DMN activity is so closely associated with not paying attention that scientists found that they could use it to predict people making a mistake on a concentration task almost 30 seconds in advance—just by seeing the DMN activity increasing.[24]

The discovery of the DMN has raised a number of very interesting questions about the human brain. For one thing, it suggests that the brain is never actually at rest. As a child, I thought that people's brains just shut off while sleeping, sort of like turning off the TV. And this was more or less the scientific view of the brain for a long time. But

[24] John Cacioppo, Laura Freberg . *Discovering Psychology: The Science of Mind* (Boston: Cengage Learning, 2016).

actually, your brain is just about as active (something like +/-5 percent)[25] while you're sleeping as when you're awake. Think about that for a moment: that's like saying that your car uses almost as much gas when it's parked in the garage with the engine turned off as when you're driving at 70 MPH down the highway. How is that even possible? The answer seems to be that the unconscious—the activity of the brain normally unavailable to conscious introspection—is doing all the heavy lifting below conscious awareness. That means that when you're asleep, and consciousness is diminished or absent, it doesn't really subtract from overall brain activity that much because the unconscious mind is still hard at work. In essence, your brain is always going 70 MPH down the highway, whether you're asleep or not.

A second question revolves around the fact that studies have shown that increased activity and connectivity in the DMN is directly correlated with difficult mental afflictions such as depression, anxiety, addiction, and obsession.[26] The mind wandering state really is an unhappy one, generally. But if the DMN is associated with such distressing conditions, why would it have evolved to be the normal mode of the brain? It seems unlikely (although not impossible) that evolution would have selected for mental illness in humans. Are we hardwired to be unhappy?

The answer is probably related to the DMN's role in planning. The advanced capacity for prognostication was a tremendous survival advantage for our hominid ancestors. Humans can make detailed plans for things that are years away in time and miles away in space. It is what allowed us to become the dominant species on this planet.

However, we don't live in the simple savannah environment we evolved to survive in. As our technology and societies have grown more and more complex, it may be that the DMN now has a bit too much work to do. The complexity of our current environment requires a quantity and intricacy of planning that is likely far beyond anything ever needed in the past. So it's not that evolution selected for mental illness, it's that we didn't evolve to live in a world this labyrinthine, entangled, and interconnected. There are so many variables and contingencies that the planning function in your brain just

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[25] Takamitsu Watanabea, Shigeyuki Kan, Takahiko Koike, Masaya Misaki, Seiki Konishi, Satoru Miyauchi, Yasushi Miyahsita, Naoki Masuda. "Network-dependent modulation of brain activity during sleep." *Neuroimage* 98 (2014). doi:10.1016/j.neuroimage.2014.04.079

A.N. Shepovalnikov, M.N. Tsitseroshin, E.I. Galperina, V.P. Rozhkov, O.V. Kruchinina, L.G. Zaitseva, E.A. Panasevich. "Characteristics of integrative brain activity during various stages of sleep and in transitional states." *Human Physiology* 38:3 (2012). doi:10.1134/S0362119712030127.

[26] R.L. Buckner, J.R. Andrews-Hanna, D.L. Schacter , "The brain's default network: Anatomy, function, and relevance to disease." in *The Year in Cognitive Neuroscience 2008,* eds A. Kingstone, M.B. Miller (Malden, MA: Blackwell Publishing,2008). pp 1–38.

has too much to deal with. Have you ever laid awake at night just planning and planning and planning? This unfortunate condition is probably not going to go away anytime soon, since society and technology seem to be getting ever more complex each year. But there is good news: any activity that induces a "flow state," which is a condition of high concentration on the activities of the present moment, such as what occurs if you're completely engaged in playing sports or music—pulls your consciousness out of default mode network activity, out of distracted daydreaming, and into the electrifying and joyous present moment.

Is there a meditation practice we can do to turn off the DMN activity? Let's try an experiment with that now. Most meditation practices put you into concentration, particularly on present-moment awareness—a task that pulls you out of the DMN and into a flow state. But there's an interesting variation possible here, which is that you don't necessarily have to focus on any particular thing, like the sensations of breathing or relaxing. Instead, it's only necessary to stay focused on whatever's happening in the present moment. Present-moment awareness drags you down out of the clouds and mist of fantasy and memory and into the concrete reality of the now—a practice traditionally called "open monitoring."

The instructions for open monitoring are simple: keep awareness in the present moment. Any time you find yourself "time traveling" to thoughts of the past or future, gently refocus awareness onto the present moment. It doesn't matter what you're noticing or even if your attention shifts from object to object continuously; all that matters is that you stay present. My favorite labeling technique while doing this is "wake up," although some people prefer just labeling as "present, present."

A huge advantage of open monitoring is that you can do it literally every waking moment while engaging in all the activities of your day. And from what neuroscience (and experience) tells us, staying in the present moment will make you happier than before.

Pushing the Button

Have you ever noticed how much fun it is to look at a menu in a restaurant? There are all the different meals, the interesting descriptions, the possible tastes you could enjoy. Then, after you've decided and ordered, the anticipation of waiting for the food often eclipses the pleasure of actually eating the meal that eventually arrives. We as a species love anticipation. And it turns out that humans are not the only creatures who feel that way.

If you train a monkey to push a lever to receive food, you'll notice something interesting: its levels of dopamine—the "reward" chemical in the brain—spike *just before* it presses the lever. Once the food arrives, dopamine returns to normal, meaning that the monkey enjoyed the feeling of anticipating getting the food more than actually getting it. It's that sense, in human terms, of, "Oh, yes, I'm gonna press that lever and get some food!" that is so pleasurable.[27]

[27] Tomas Ljungberg, Paul Apicella, Wolfram Sschultz. "Responses of Monkey Dopamine Neurons

Research with rats shows just how powerful this anticipation of pleasure really is. If you give a rat a button to stimulate the dopamine pathway of its own brain, something quite intense occurs. The rat will press the button, and press the button, and press the button, over and over and never reach satisfaction. The rat will become crazed, strung out, frenzied—pushing the button until it collapses. Rats will keep hammering away like kids playing a video game instead of eating food or drinking water, no matter how hungry or tired they become. They stop grooming themselves, and female rats neglect their young.[28]

Researchers have done similar experiments—sometimes accidentally—on human beings with similar results. One woman had an electrode implanted in her thalamus to control severe pain, which is an effective treatment.[29] In her case, however, the electrode was slightly misplaced, and instead triggered a dopamine center in the brain, causing an intense sexual feeling. Given a button she could push herself, the woman proceeded to stimulate it more or less continuously. While it didn't bring her to orgasm, the erotic sensation was profoundly euphoric. Her behavior was hard to distinguish from that of the rats. As the researches put it: "…the patient self-stimulated throughout the day, neglecting her personal hygiene and family commitments. A chronic ulceration developed at the tip of the finger used to adjust the amplitude dial and she frequently tampered with the device in an effort to increase the stimulation amplitude. At times she implored her family to limit her access to the stimulator, each time demanding its return after a short hiatus."

Dopamine is a neurotransmitter that animals, including humans, will do almost anything to get. Once able to get all they want, an animal will exhibit the classic behavior of a "junkie," forgoing all other concerns—food, sex, sleep, children, friends—just to get another "hit." For many years, researchers believed that all the lever-pushing was triggering the reward circuits in the brain, and that this dopamine high was evolution's way of getting you to do something life-positive.

But Washington State University researcher Jaak Panksepp, a controversial researcher at the cutting edge of neuroscience, wasn't so sure. After working for years with rats, he realized that the lever-pushing rats didn't seem to exhibit the behavior of satisfaction you'd expect if the region they were stimulating had to do with reward. Whether it's hunger, thirst, sex, or other drives, any mammal will take as much as they want, and then be satisfied, becoming euphoric and relaxed and then resting, or doing something else.

During Learning of Behavioral Reactions." *Journal of Neurophysiology* 67:1 (1992). http://www.p.u-tokyo.ac.jp/~kyama/kitazawaz/Ljungberg1992.pdf

[28] James Olds, Peter Milner. "Positive reinforcement produced by electrical stimulation of septal area and other regions of rat brain." *Journal of Comparative and Physiologal Psychology* 47:6 (1954). doi:10.1037/h0058775

[29] Russell K. Portenoy, Jens O. Jarden, John J. Sidtis, Richard B. Lipton, Kathleen M. Foley, David A. Rottenberg. "Compulsive thalamic self-stimulation: a case with metabolic, electrophysiologic and behavioral correlates."*Pain* 27:3 (1986). doi:10.1016/0304-3959(86)90155-7.

But whether it was a rat, a monkey, or a human being, that's not what was happening. Instead, there was the kind of crazed behavior just described. Panksepp observed that each "stimulation evoked a reinvigorated search strategy," and he realized something important—these are not reward circuits, but what he calls "seeking" behavior circuits.[30] These are the brain networks that cause animals to get up in the morning, go out, and get something done.

The dopamine circuits give animals a sense of purpose and directed action. And it's not just about food or sex, either. Humans are unique in that we can become motivated about abstract concepts or fantasies. So, we can get excited about searching for things that are non-physical, such as spiritual enlightenment—there's a reason that such people are called "seekers." Whether it's something as lofty as the pursuit of happiness or as mundane as completing a thorny crossword puzzle, the human dopamine system can be revved up by ideas and tasks that no animal ever would.

We want to keep the dopamine circuits aroused as much as possible. So much so, in fact, that we often choose to do that using illegal drugs such as cocaine, methamphetamine, and others that directly stimulate dopamine. Most drugs that people like to use recreationally stimulate the brain to release a flood of dopamine, which creates the pleasurable feeling of getting high. Eventually your brain adjusts to these big bursts of dopamine, so you have to use more and more of the drug to try to score the same high.

But dopamine is not just about drugs, it's about *any* addiction—especially things that amp up our sense of anticipation or seeking. It may even be why people get so hooked on the Internet or their smartphones. You click and click and click and keep hoping to find something cool, interesting, or useful. Try to pry the smartphone out of the hands of a teenager and you'll see the intensity of the addiction. There might be an important text coming at any second! Something fascinating might happen at any time!

Is there any practice to help you to cope with or reduce addictive urges? According to Dr. Judson Brewer,[31] the answer is found in a simple but effective mindfulness practice. The idea is to bring awareness to the actual physical sensations of the urge to take action on an addictive behavior. Most of the time, people don't actually take the time to sit with the feeling of these drives, but instead move immediately into attempting to fulfill them.

The practice is to notice when an addictive urge—such as compulsively checking your email, eating too much, smoking a cigarette, or whatever—arises. When that happens, decide to take no action for two full minutes. Instead, practice mindfulness of body sensations around the feelings of the urge. Is it a sense of tension in the stomach? A tightness in the chest? Sweat on your forehead? Or something else? Whatever the

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[30] From his book *Affective Neuroscience: The Foundations of Human and Animal Emotions* (New York: Oxford University Press, 1998). Accessed athttps://books.google.com/books?id=qqcRGagyEuAC&lpg=PP1&pg=PP1#v=onepage&q&f=false

[31] Judson Brewer. "A simple way to break a bad habit." YouTube video, 9:24, posted by "TED" February 24, 2016. https://www.youtube.com/watch?v=-moW9jvvMr4.

symptoms are, spend two minutes just feeling them with as much curiosity and openness as possible. After that, you can take whatever action you were planning, but remember the feelings. Over time, contemplating them like this can make your ability to tolerate the urge much larger—giving you much more control over it.

Onward, Upward, Inward

The mechanism of addiction, the downtime of the brain, the role of caring connection, how fear controls us, and even the infinite capacity for the brain to learn—these represent the merest smattering of the endlessly interesting discoveries about the brain that have a direct influence on your life. It's beyond my abilities to list even one percent of the amazing things we've discovered about our brains in the past few years, but hopefully I've ignited your curiosity enough so that you'll go out and learn more for yourself. It is perhaps the most rewarding journey you will ever make.