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How electrical brain stimulation can change the way we think

After my brain was jolted, says Sally Adee, I had a near-spiritual experience

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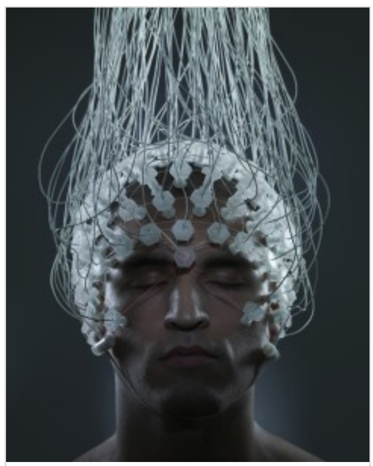
Researchers have found that "transcranial direct current stimulation" can more than double the rate at which people learn a wide range of tasks, such as object recognition, math skills, and marksmanship. *Photo: Adrianna Williams/Corbis*

HAVE YOU EVER wanted to take a vacation from your own head? You could do it easily enough with liberal applications of alcohol or hallucinogens, but that's not the kind of vacation I'm talking about. What if you could take a very specific vacation only from the stuff that makes it painful to be you: the sneering inner monologue that insists you're not capable enough or smart enough or pretty enough, or whatever hideous narrative rides you. Now that would be a vacation. You'd still be you, but you'd be able to navigate the world without the emotional baggage that now drags on your every decision. Can you imagine what that would feel like?

Late last year, I got the chance to find out, in the course of investigating a story for *New Scientist* about how researchers are using neurofeedback and electrical brain stimulation to accelerate learning. What I found was that electricity might be the most powerful drug I've ever used in my life.

It used to be just plain old chemistry that had neuroscientists gnawing their fingernails about the ethics of brain enhancement. As Adderall, Ritalin, and other cognitive enhancing drugs gain widespread acceptance as tools to improve your everyday focus, even the stigma of obtaining them through less-than-legal channels appears to be disappearing. People will overlook a lot of moral gray areas in the quest to juice their brain power.

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But until recently, you were out of luck if you wanted to do that without taking drugs that might be addictive, habit-forming, or associated with unfortunate behavioral side effects. Over the past few years, however, it's become increasingly clear that applying an electrical current to your head confers similar benefits.

U.S. military researchers have had great success using "transcranial direct current stimulation" (tDCS) — in which they hook you up to what's essentially a 9-volt battery and let the current flow through your brain. After a few years of lab testing, they've found that tDCS can more than double the rate at which people learn a wide range of tasks, such as object recognition, math skills, and marksmanship.

We don't yet have a commercially available "thinking cap," but we will soon. So the research community has begun to ask: What are the ethics of battery-operated cognitive enhancement? Recently, a group of Oxford neuroscientists released a cautionary statement about the ethics of brain boosting; then the U.K.'s Royal Society released a report that questioned the use of tDCS for military applications. Is brain boosting a fair addition to the cognitive enhancement arms race? Will it create a Morlock/Eloi–like social divide, where the rich can afford to be smarter and everyone else will be left behind? Will Tiger Moms force their lazy kids to strap on a zappity helmet during piano practice?

After trying it myself, I have different questions. To make you understand, I am going to tell you how it felt. The experience wasn't simply about the easy pleasure of undeserved expertise. For me, it was a near-spiritual experience. When a nice neuroscientist named Michael Weisend put the electrodes on me, what defined the experience was not feeling smarter or learning faster: The thing that made the earth drop out from under my feet was that for the first time in my life, everything in my head finally shut up.

The experiment I underwent was accelerated marksmanship training, using a training simulation that the military uses. I spent a few hours learning how to shoot a modified M4 close-range assault rifle, first without tDCS and then with. Without it I was terrible, and when you're terrible at something, all you can do is obsess about how terrible you are. And how much you want to stop doing the thing you are terrible at.

Then this happened:

THE 20 MINUTES I spent hitting targets while electricity coursed through my brain were far from transcendent. I only remember feeling like I'd just had an excellent cup of coffee, but without the caffeine jitters. I felt clear-headed and like myself, just sharper. Calmer. Without fear and without doubt. From there on, I just spent the time waiting for a problem to appear so that I could solve it.

It was only when they turned off the current that I grasped what had just happened. Relieved of the minefield of self-doubt that constitutes my basic personality, I was a hell of a shot. And I can't tell you how stunning it was to suddenly understand just how much of a drag that inner cacophony is on my ability to navigate life and basic tasks.

It's possibly the world's biggest cliché that we're our own worst enemies. In yoga, they tell you that you need to learn to get out of your own way. Practices like yoga are meant to help you exhume the person you are without all the geologic layers of narrative and cross talk that are constantly chattering in your brain. I think eventually they just become background noise. We stop hearing them consciously, but believe me, we

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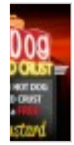

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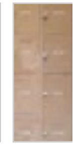

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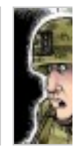

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listen to them just the same.

My brain without self-doubt was a revelation. There was suddenly this incredible silence in my head; I've experienced something close to it during two-hour Iyengar yoga classes, or at the end of a 10k, but the fragile peace in my head would be shattered almost the second I set foot outside the calm of the studio. I had certainly never experienced instant Zen in the frustrating middle of something I was terrible at.

WHAT HAD HAPPENED inside my skull? One theory is that the mild electrical shock may depolarize the neuronal membranes in the part of the brain associated with object recognition, making the cells more excitable and responsive to inputs. Like many other neuroscientists working with tDCS, Weisend thinks this accelerates the formation of new neural pathways during the time that someone practices a skill, making it easier to get into the "zone." The method he was using on me boosted the speed with which wannabe snipers could detect a threat by a factor of 2.3.

Another possibility is that the electrodes somehow reduce activity in the prefrontal cortex — the area of the brain used in critical thought, says psychologist Mihaly Csikszentmihalyi of Claremont Graduate University in California. And critical thought, some neuroscientists believe, is muted during periods of intense Zen-like concentration. It sounds counterintuitive, but silencing self-critical thoughts might allow more automatic processes to take hold, which would in turn produce that effortless feeling of flow.

With the electrodes on, my constant self-criticism virtually disappeared, I hit every one of the targets, and there were no unpleasant side effects afterwards. The bewitching silence of the tDCS lasted, gradually diminishing over a period of about three days. The inevitable return of self-doubt and inattention was disheartening, to say the least.

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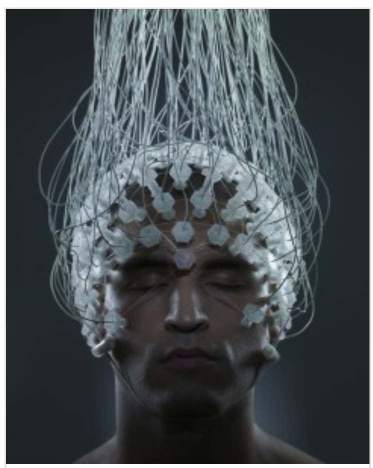
Researchers have found that "transcranial direct current stimulation" can more than double the rate at which people learn a wide range of tasks, such as object recognition, math skills, and marksmanship. *Photo: Adrianna Williams/Corbis*

I HOPE YOU can sympathize with me when I tell you that the thing I wanted most acutely for the weeks following my experience was to go back and strap on those electrodes. I also started to have a lot of questions. Who was I apart from the angry bitter gnomes that populate my mind and drive me to failure because I'm too scared to try? And where did those voices come from? Some of them are personal history, like the caustically dismissive 7th grade science teacher who advised me to become a waitress. Some of them are societal, like the hateful lady-mag voices that bully me every time I look in a mirror. An invisible narrative informs all my waking decisions in ways I can't even keep track of.

What would a world look like in which we all wore little tDCS headbands that would keep us in a primed, confident state, free of all doubts and fears? I'd wear one at all times and have two in my backpack ready in case something happened to the first one.

I think the ethical questions we should be asking about tDCS are much more subtle than the ones we've been asking about cognitive enhancement. Because how you define "cognitive enhancement" frames the debate about its ethics.


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If you told me tDCS would allow someone to study twice as fast for the bar exam, I might be a little leery because now I have visions of rich daddies paying for Junior's thinking cap. Neuroscientists like Roy Hamilton have termed this kind of application "cosmetic neuroscience," which implies a kind of "First World problem" — frivolity.

But now think of a different application — could school-age girls use the zappy cap while studying math to drown out the voices that tell them they can't do math because they're girls? How many studies have found a link between invasive stereotypes and poor test performance?

And then, finally, the main question: What role do doubt and fear play in our lives if their eradication actually causes so many improvements? Do we make more ethical decisions when we listen to our inner voices of self-doubt or when we're freed from them? If we all wore these caps, would the world be a better place?

And if tDCS headwear were to become widespread, would the same 20 minutes with a 2 milliamp current always deliver the same effects, or would you need to up your dose like you do with some other drugs?

Because, to steal a great point from an online commenter, pretty soon, a 9-volt battery may no longer be enough.

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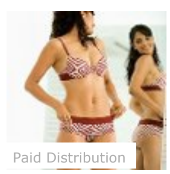


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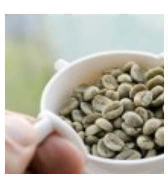
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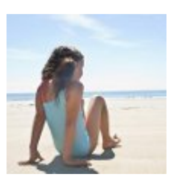
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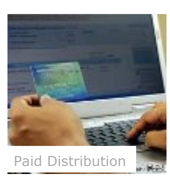

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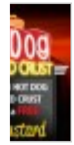

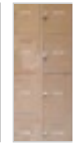
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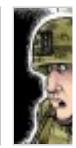

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Zap your brain into the zone: Fast track to pure focus

06 February 2012 by **Sally Adee**
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Whether you want to smash a forehand like Federer, or just be an Xbox hero, there is a shocking short cut to getting the brain of an expert

Zen and the art of genius *(Image: The Red Dress)*

I'm close to tears behind my thin cover of sandbags as 20 screaming, masked men run towards me at full speed, strapped into suicide bomb vests and clutching rifles. For every one I manage to shoot dead, three new assailants pop up from nowhere. I'm clearly not shooting fast enough, and panic and incompetence are making me continually jam my rifle.

My salvation lies in the fact that my attackers are only a video, projected on screens to the front and sides. It's the very simulation that trains US troops to take their first steps with a rifle, and everything about it has been engineered to feel like an overpowering assault. But I am failing miserably. In fact, I'm so demoralised that I'm tempted to put down the rifle and leave.

Then they put the electrodes on me.

I am in a lab in Carlsbad, California, in pursuit of an elusive mental state known as "flow" - that feeling of effortless concentration that characterises outstanding performance in all kinds of skills.

Flow has been maddeningly difficult to pin down, let alone harness, but a wealth of new technologies could soon allow us all to conjure up this state. The plan is to provide a short cut to virtuosity, slashing the amount of time it takes to master a new skill - be it tennis, playing the piano or marksmanship.

That will be welcome news to anyone embarking on the tortuous road to expertise. According to pioneering research by Anders Ericsson at Florida State University in Tallahassee, it normally takes 10,000 hours of practice to become expert in any discipline. Over that time, your brain knits together a wealth of new circuits that eventually allow you to execute the skill automatically, without consciously considering each action. Think of the way tennis champion Roger Federer, after years of training, can gracefully combine a complicated series of actions - keeping one eye on the ball and the other on his opponent, while he lines up his shot and then despatches a crippling backhand - all in one stunningly choreographed second.

Flow typically accompanies these actions. It involves a Zen-like feeling of intense concentration, with time seeming to stop as you focus completely on the activity in hand. The experience crops up repeatedly when experts describe what it feels like to be at the top of their game, and with years of practice it becomes second nature to enter that state. Yet you don't have to be a pro to experience it - some people report the same ability to focus at a far earlier stage in their training, suggesting they are more naturally predisposed to the flow state than others. This effortless concentration should speed up progress, while the joyful feelings that come with the flow state should help take the sting out of further practice, setting such people up for future success, says Mihaly Csikszentmihalyi at Claremont Graduate University in California. Conversely, his research into the flow state in children showed that, as he puts it, "young people who didn't enjoy the pursuit of the subject they were gifted in, whether it was mathematics or music, stopped developing their skills and reverted to mediocrity."

Despite its potentially crucial role in the development of talent, many researchers had deemed the flow state too slippery a concept to tackle - tainted as it was with mystical, meditative connotations. In the late 1970s, Csikszentmihalyi, then a psychologist at the University of Chicago, helped change that view by showing that the state could be defined and studied empirically. In one groundbreaking study, he interviewed a few hundred talented people, including athletes, artists, chess players, rock climbers and surgeons, enabling him to pin down four key features that characterise flow.

The first is an intense and focused absorption that makes you lose all sense of time. The second is what is known as autotelicity, the sense that the activity you are engaged in is rewarding for its own sake. The third is finding the "sweet spot", a feeling that your skills are perfectly matched to the task at hand, leaving you neither frustrated nor bored. And finally, flow is characterised by automaticity, the sense that "the piano is playing itself", for example.

Exactly what happens in the brain during flow has been of particular interest, but it has been tricky to measure. Csikszentmihalyi took an early stab at it, using electroencephalography (EEG) to measure the brain waves of expert chess players during a game. He found that the most skilled players showed less activity in the prefrontal cortex, which is typically associated with higher cognitive processes such as working memory and verbalisation. That may seem counter-intuitive, but silencing self-critical thoughts might allow more automatic processes to take hold, which would in turn produce that effortless feeling of flow.

Later studies have confirmed these findings and revealed other neural signatures of flow. Chris Berka and her colleagues at Advanced Brain Monitoring in Carlsbad, California, for example, looked at the brain waves of Olympic archers and professional golfers. A few seconds before the archers fired off an arrow or the golfers hit the ball, the team spotted a small increase in what's known as the alpha band, one of the frequencies that arises from the electrical noise of all the brain's neurons (*The International Journal of Sport and Society*, vol 1, p 87). This surge in alpha waves, Berka says, is associated with reduced activation of the cortex, and is always more obvious in experts than in novices. "We think this represents focused attention on the target, while other sensory inputs are suppressed," says Berka. She found that these mental changes are accompanied by slower breathing and a lower pulse rate - as you might expect from relaxed concentration.

Defining and characterising the flow state is all very well, but could a novice learn to turn off their critical faculties and focus their attention in this way, at will? If so, would it boost performance? Gabriele Wulf, a kinesiologist at the University of Nevada at Las Vegas, helped to answer this question in 1998, when she and her colleagues examined the way certain athletes move (*Journal of Motor Behavior*, vol 30, p 169).

At the time, she had no particular interest in the flow state. But Wulf and her colleagues found that they could quickly improve a person's abilities by asking them to focus their attention on an external point away from their body. Aspiring skiers who were asked to do slalom-type movements on a simulator, for example, learned faster if they focused on a marked spot ahead of them. Golfers who focused on the swing of the club were about 20 per cent more accurate than those who focused on their own arms.

Wulf and her colleagues later found that an expert's physical actions require fewer muscle movements than those of a beginner - as seen in the tight, spare motions of top-flight athletes. They also experience less mental strain, a lower heart rate and shallower breathing - all characteristics of the flow state (*Human Movement Science*, vol 29, p 440).

These findings were borne out in later studies of expert and novice swimmers. Novices who concentrated on an external focus - the water's movement around their limbs - showed the same effortless grace as those with more experience, swimming faster and with a more efficient technique. Conversely, when the expert swimmers focused on their limbs, their performance declined (*International Journal of Sport Science & Coaching*, vol 6, p 99).

Wulf's findings fit well with the idea that flow - and better learning - comes when you turn off conscious thought. "When you have an external focus, you achieve a more automatic type of control," she says. "You don't think about what you are doing, you just focus on the outcome."

Berka has been taking a different approach to evoke the flow state - her group is training novice marksmen to use neurofeedback. Each person is hooked up to electrodes that tease out and display specific brain waves, along with a monitor that measures their heartbeat. By controlling their breathing and learning to deliberately manipulate the waveforms on the screen in front of them, the novices managed to produce the alpha waves characteristic of the flow state. This, in turn, helped them improve their accuracy at hitting the targets. In fact, the time it took to shoot like a pro fell by more than half (*The International Journal of Sport and Society*, vol 1, p 87).

But as I found when I tried the method, even neurofeedback has a catch. It takes time and effort to produce really thrumming alpha waves. Just when I thought I had achieved them, they evaporated and I lost my concentration. Might there be a faster way to force my brain into flow? The good news is that there, too, the answer appears to be yes.

That is why I'm now allowing Michael Weisend, who works at the Mind Research Network in Albuquerque, New Mexico, to hook my brain up to what's essentially a 9-volt battery. He sticks the anode - the positive pole of the battery - to my temple, and the cathode to my left arm. "You're going to feel a slight tingle," he says, and warns me that if I remove an electrode and break the connection, the voltage passing through my brain will blind me for a good few seconds.

Weisend, who is working on a US Defense Advanced Research Projects Agency programme to accelerate learning, has been using this form of transcranial direct current stimulation (tDCS) to cut the time it takes to train snipers. From the electrodes, a 2-milliamp current will run through the part of my brain associated with object recognition - an important skill when visually combing a scene for assailants.

The mild electrical shock is meant to depolarise the neuronal membranes in the region, making the cells more excitable and responsive to inputs. Like many other neuroscientists working with tDCS, Weisend thinks this accelerates formation of new neural pathways during the time that someone practises a skill. The method he is using on me boosted the speed with which wannabe snipers could detect a threat by a factor of 2.3 (*Experimental Brain Research*, vol 213, p 9).

Mysteriously, however, these long-term changes also seem to be preceded by a feeling that emerges as soon as the current is switched on and is markedly similar to the flow state. "The number one thing I hear people say after tDCS is that time passed unduly fast," says Weisend. Their movements also seem to become more automatic; they report calm, focused concentration - and their performance improves immediately.

It's not yet clear why some forms of tDCS should bring about the flow state. After all, if tDCS were solely about writing new memories, it would be hard to explain the improvement that manifests itself as soon as the current begins to flow.

One possibility is that the electrodes somehow reduce activity in the prefrontal cortex - the area used in critical thought, which Csikszentmihalyi had found to be muted during flow. Roy Hamilton, a neuroscientist at the University of Pennsylvania in Philadelphia, thinks this may happen as a side effect of some forms of tDCS. "tDCS might have much more broad effects than we think it does," he says. He points out that some neurons can mute the signals of other brain cells in their network, so it is possible that stimulating one area of the brain might reduce activity in another.

Uncertain effect

Others are more sceptical. Arne Dietrich of the American University of Beirut, Lebanon, suspects that learning will be impaired if the frontal cortex isn't initially engaged in the task. What's more, he thinks you would need a specialised type of tDCS to dampen activity in the prefrontal cortex. "But then again, it is not clear what sort of ripple effect tDCS has globally," he concedes, "regardless of which brain area is targeted."

In any case, it is clear that not all forms of tDCS bring about flow. Roi Cohen Kadosh at the University of Oxford certainly saw no signs of it when he placed an anode over the brain regions used in spatial reasoning.

This debate will only be resolved with much more research. For now, I'm intrigued about what I'll experience as I ask Weisend to turn on the current. Initially, there is a slight tingle, and suddenly my mouth tastes like I've just licked the inside of an aluminium can. I don't notice any other effect. I simply begin to take out attacker after attacker. As twenty of them run at me brandishing their guns, I calmly line up my rifle, take a moment to breathe deeply, and pick off the closest one, before tranquilly assessing my next target.

In what seems like next to no time, I hear a voice call out, "Okay, that's it." The lights come up in the simulation room and one of the assistants at Advanced Brain Monitoring, a young woman just out of university, tentatively enters the darkened room.

In the sudden quiet amid the bodies around me, I was really expecting more assailants, and I'm a bit disappointed when the team begins to remove my electrodes. I look up and wonder if someone wound the clocks forward. Inexplicably, 20 minutes have just passed. "How many did I get?" I ask the assistant.

She looks at me quizzically. "All of them."

Diy brain enhancement

Zapping your brain with a small current seems to improve everything from mathematical skills to marksmanship, but for now your best chance of experiencing this boost is to sign up for a lab experiment. Machines that provide transcranial direct current stimulation (tDCS) cost £5000 a pop, and their makers often sell them only to researchers.

That hasn't stopped a vibrant community of DIY tDCS enthusiasts from springing up. Their online forums are full of accounts of their home-made experiments, including hair-curling descriptions of blunders that, in one case, left someone temporarily blind.

What drives people to take such risks? Roy Hamilton, a neuroscientist at the University of Pennsylvania in Philadelphia, thinks it is part of a general trend he calls cosmetic neuroscience, in which people try to tailor their brains to the demands of an increasingly fast-paced world. "In a society where both students and their professors take stimulant medications to meet their academic expectations," he warns, "the potential pressure for the use of cognitive enhancing technologies of all types is very real".

***Sally Adee** is a technology feature editor at New Scientist*

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Amping Up Brain Function: Transcranial Stimulation Shows Promise in Speeding Up Learning

Electrical stimulation of subjects' brains is found to accelerate learning in military and civilian subjects, although researchers are yet wary of drawing larger conclusions about the mechanism

By R. Douglas Fields | Friday, November 25, 2011 | 23 comments

WASHINGTON, D.C.—One of the most difficult tasks to teach Air Force pilots who guide unmanned attack drones is how to pick out targets in complex radar images. Pilot training is currently one of the biggest bottlenecks in deploying these new, deadly weapons.

So Air Force researchers were delighted recently to learn that they could cut training time in half by delivering a mild electrical current (two milliamperes of direct current for 30 minutes) to pilot's brains during training sessions on video simulators. The current is delivered through EEG (electroencephalographic) electrodes placed on the scalp. Biomedical engineer Andy McKinley and colleagues at the Air Force Research Laboratory at Wright–Patterson Air Force Base, reported their finding on this so-called transcranial direct current stimulation (TDCS) here at the Society for Neuroscience annual meeting on November 13.

"I don't know of anything that would be comparable," McKinley said, contrasting the cognitive boost of TDCS with, for example, caffeine or other stimulants that have been tested as enhancements to learning. TDCS not only accelerated learning, pilot accuracy was sustained in trials lasting up to 40 minutes. Typically accuracy in identifying threats declines steadily after 20 minutes. Beyond accelerating pilot training, TDCS could have many medical applications in the military and beyond by accelerating retraining and recovery after brain injury or disease.

The question for the Air Force and others interested in transcranial stimulation is whether these findings will hold up over time or will land in the dustbin of pseudoscience.

"There is so much pop science out there on this right now," says neurobiologist Rex Jung of the University of New Mexico Health Sciences Center in Albuquerque, referring to sensational media reports, the widely varying protocols and sometimes lax controls used in different studies of brain stimulation to power learning or elevate mood.

Indeed, electrical stimulation for therapeutic effect has a long and checkered history extending back to the 19th century when "electrotherapy" was the rage among adventurous medical doctors as well as quacks. Pulses of electric current were applied to treat a wide range of conditions from insomnia to uterine cancer. The placebo effect might have been at work in the case of those historical results, and although the experiments were carefully controlled, it is unclear to skeptics if it is a factor in the case of the Air Force's research on transcranial stimulation and learning.

Subjects definitely register the stimulation, but it is not unpleasant. "It feels like a mild tickling or slight burning," says undergraduate student Lauren Bullard, who was one of the subjects in another study on TDCS and learning reported at the meeting, along with her mentors Jung and Michael Weisend and colleagues of the Mind Research Network in Albuquerque. "Afterward I feel more alert," she says. But why?

Bullard and her co-authors sought to determine if they could measure any tangible changes in the brain after TDCS, which could explain how the treatment accelerates learning. The researchers looked for both functional changes in the brain (altered brain-wave activity) and physical changes (by examining MRI brain scans) after TDCS.

They used magnetoencephalography (MEG) to record magnetic fields (brain waves) produced by sensory stimulation (sound, touch and light, for example), while test subjects received TDCS. The researchers reported that TDCS gave a six-times baseline boost to the amplitude of a brain wave generated in response to stimulating a sensory nerve in the arm. The boost was not seen when mock TDCS was used, which produced a similar sensation on the scalp, but was ineffective in exciting brain tissue. The effect also persisted long after TDCS was stopped. The sensory-evoked brain wave remained 2.5 times greater than normal 50 minutes after TDCS. These results suggest that TDCS increases cerebral cortex excitability, thereby heightening arousal, increasing responses to sensory input, and accelerating information processing in cortical circuits.

Remarkably, MRI brain scans revealed clear structural changes in the brain as soon as five days after TDCS. Neurons in the cerebral cortex connect with one another to form circuits via massive bundles of nerve fibers (axons) buried deep below the brain's surface in "white matter tracts." The fiber bundles were found to be more robust and more highly organized after TDCS. No changes were seen on the opposite side of the brain that was not stimulated by the scalp electrodes.

The structural changes in white matter detected by the MRI technique, called diffusion tensor imaging (DTI), could be caused by a number of microscopic physical or cellular alterations in brain tissue, but identifying those is impossible without obtaining samples of the tissue for analysis under a microscope.

An expert on brain imaging, Robert Turner of the Department of Neurophysics at the Max Planck Institute for Human Cognitive and Brain Sciences, in Leipzig, Germany, who was not involved in the study, speculated that the changes detected by DTI could represent an increase in insulation on the fibers (myelin) that would speed transmission of information through the fibers. "In my present view, the leading hypothesis for the observed rapid changes...is that previously unmyelinated axonal fibers within white matter become rapidly myelinated when they start to carry frequent action potentials," he says. There are, however, several other possible explanations, he cautions.

Matthias Witkowski, now at the Institute for Medicine, Psychology and Behavioral Neurobiology at the University of Tübingen in Germany, described the rapid changes in white matter in these experiments as "incredible." "That [white matter changes] would not have been my first guess," he said. "It will be very interesting to see if there are cellular changes." This is the next step in research planned by Jung and colleagues. They hope to obtain brain tissue from patients who would be willing to participate in TDCS studies prior to undergoing necessary brain surgery in which tissue would be removed as a required part of their treatment.

Witkowski is convinced by these new studies and his own research that transcranial stimulation can accelerate many kinds of learning, and research on brain–machine interfacing, which he presented at the meeting, demonstrates the potential for TDCS in speeding patient rehabilitation after injury. People with paralyzed limbs can be taught to control a robotic glovelike device that will move their fingers in response to the patient's own thoughts. Electrodes on the person's scalp pick up brain waves as the person imagines moving his or her hand. The brain waves are analyzed by a computer to control the robotic artificial hand. But learning to generate the proper brain waves to control the artificial hand through thought alone requires considerable training. Witkowski found that if patients received 20 minutes of TDCS stimulation once during five days of training, they learned to control the hand with their thoughts much more rapidly.

The new studies reported at this meeting suggest that there is far more to speed learning produced by TDCS than can be explained by the placebo effect. And the evidence now shows that TDCS produces physical changes in the brain's structure as well as physiological changes in its response. TDCS increases cortical excitability, which can be measured in recordings of brain waves, and it also causes changes in the structure of the brain's connections that can be observed on an MRI. By using electricity to energize neural circuits in the cerebral cortex, researchers are hopeful that they have found a harmless and drug-free way to double the speed of learning.

Bloomberg Businessweek

Technology

How to Remember More With Electricity: Michael Weisend

By Michael Weisend on April 12, 2012

A few years ago, I was talking to an admiral. He said, "Son, I get better and better equipment every year, but I get dumber and dumber guys to run it." He wanted me to help his troops retain more of their training. The idea would be to employ training strategies to minimize the drop-off in proficiency between training sessions. That's where we think transcranial direct-current stimulation (TDCS), the application of a low electrical current directly to the brain, may be helpful.

TDCS essentially makes a piece of brain respond to a greater degree to the external stimulus. Memory is all about building connections between Structure A and Structure B in the brain, so if you can get a bigger response out of a piece of brain, you have more active tissue, and it's easier to build those bridges between Area A and Area B. TDCS allows you to transition from the novice state to the expert state more rapidly. I do think this is a technology that will get to the public, eventually. But it isn't like Tylenol, where you think, "My headache's not going away, so I'll just crank up the dosage." I see people on the Internet jury-rigging their own TDCS devices to try to jump-start their brains. This is an extremely dangerous practice, and I have the scars to prove it. — *As told to Julian Sancton*

UAS VISION
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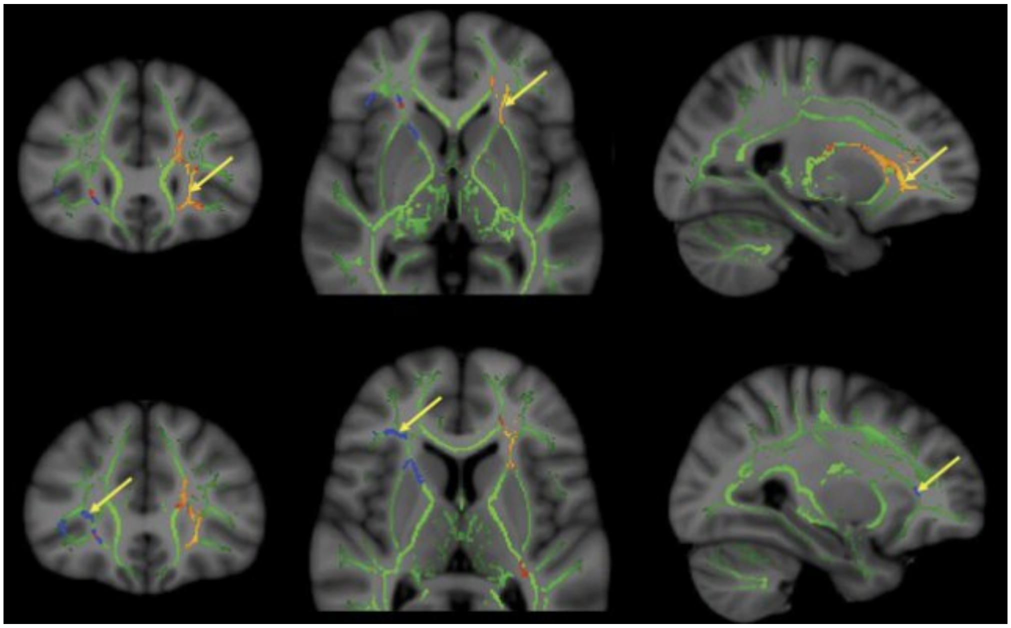
Electric Shocks to Brain Accelerate RPA Pilot Learning Process

Posted on April 6, 2012 by The Editor



Scientists at the Mind Research Network (MRN) in Albuquerque, NM have demonstrated that Transcranial Direct Current Stimulation (TDCS) enhances learning when applied to the inferior frontal and temporal cortices.

TDCS is a non-invasive form of brain stimulation applied via a weak electrical current passed between electrodes on the scalp. Recently published in professional journals Nature, Scientific American and Experimental Brain Research, TDCS facilitated training is being developed in partnership with the Department of Defense and U.S. Air Force to improve the complex skills necessary for operation of remotely piloted aircraft.

The study by Michael Weisend, Ph.D., examined the effects of TDCS delivered at the beginning of training (novice) or after an hour of training (experienced) on participants' ability to detect cues indicative of covert threats. Accuracy in classification of images containing and not containing threat stimuli during the testing sessions indicated: (1) mastery of threat detection significantly increased with training, (2) anodal TDCS significantly enhanced learning, and (3) TDCS was significantly more effective in enhancing test performance when applied in novice learners than in experienced learners.

Weisend and his fellow scientists believe TDCS might be more effective in training new recruits than in improving an existing skill set.

MRN researchers also developed novel electrode technology that increases the safety and comfort of subjects. They recorded magnetoencephalography (MEG) during brain stimulation with TDCS to document the enhanced responses to stimuli. Brain response to activation of a sensory nerve in the arm was significantly larger with TDCS compared to a mock TDCS control condition. The sensory-evoked brain wave remained 2.5 times greater than normal 30 minutes after TDCS. Results suggest that TDCS increases cerebral cortex excitability, thereby increasing responses to sensory input and accelerating memory formation.

The Mind Research Network (MRN) is an independent non-profit organization dedicated to advancing the diagnosis and treatment of mental illness and brain injury. Headquartered in Albuquerque, New Mexico, MRN consists of an interdisciplinary association of scientists located at universities, national laboratories and research centers around the world and is focused on imaging technology and its emergence as an integral element of neuroscience investigation. It is an affiliate with Lovelace Respiratory Research Institute.

Source: Press Release

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WHO CONTROLS THE PAST CONTROLS THE FUTURE. WHO CONTROLS THE PRESENT CONTROLS THE PAST.- GEORGE ORWELL

« **Reconstructing America's Economic System Is Within Reach**

There Is Nothing More Anti-Capitalist Than "The People First" »

Zap your brain into the zone: Fast track to pure focus

Whether you want to smash a forehand like Federer, or just be an Xbox hero, there is a shocking short cut to getting the brain of an expert

I'm close to tears behind my thin cover of sandbags as 20 screaming, masked men run towards me at full speed, strapped into suicide bomb vests and clutching rifles. For every one I manage to shoot dead, three new assailants pop up from nowhere. I'm clearly not shooting fast enough, and panic and incompetence are making me continually jam my rifle.

My salvation lies in the fact that my attackers are only a video, projected on screens to the front and sides. It's the very simulation that trains US troops to take their first steps with a rifle, and everything about it has been engineered to feel like an overpowering assault. But I am failing miserably. In fact, I'm so demoralised that I'm tempted to put down the rifle and leave.

Then they put the electrodes on me.

I am in a lab in Carlsbad, California, in pursuit of an elusive mental state known as "flow" – that feeling of effortless concentration that characterises outstanding performance in all kinds of skills.

Flow has been maddeningly difficult to pin down, let alone harness, but a wealth of new technologies could soon allow us all to conjure up this state. The plan is to provide a short cut to virtuosity, slashing the amount of time it takes to master a new skill – be it tennis, playing the piano or marksmanship.

That will be welcome news to anyone embarking on the tortuous road to expertise. According to pioneering research by Anders Ericsson at Florida State University in Tallahassee, it normally takes 10,000 hours of practice to become expert in any discipline. Over that time, your brain knits together a wealth of new circuits that eventually allow you to execute the skill automatically, without consciously considering each action. Think of the way tennis champion Roger Federer, after years of training, can gracefully combine a complicated series of actions – keeping one eye on the ball and the other on his opponent, while he lines up his shot and then despatches a crippling backhand – all in one stunningly choreographed second.

Flow typically accompanies these actions. It involves a Zen-like feeling of intense concentration, with time seeming to stop as you focus completely on the activity in hand. The experience crops up repeatedly when experts describe what it feels like to be at the top of their game, and with years of practice it becomes second nature to enter that state. Yet you don't have to be a pro to experience it – some people report the same ability to focus at a far earlier stage in their training, suggesting they are more naturally predisposed to the flow state than others. This effortless concentration should speed up progress, while the joyful feelings that come with the flow state should help take the sting out of further practice, setting such people up for future success, says Mihaly Csikszentmihalyi at Claremont Graduate University in California. Conversely, his research into the flow state in children showed that, as he puts it, "young people who didn't enjoy the pursuit of the subject they were gifted in, whether it was mathematics or music, stopped developing their skills and reverted to mediocrity."

Despite its potentially crucial role in the development of talent, many researchers had deemed the flow state too slippery a concept to tackle – tainted as it was with mystical, meditative connotations. In the late 1970s, Csikszentmihalyi, then a psychologist at the University of Chicago, helped change that view by showing that the state could be defined and studied empirically. In one groundbreaking study, he interviewed a few hundred talented people, including athletes, artists, chess players, rock climbers and surgeons, enabling him to pin down four key features that characterise flow.

The first is an intense and focused absorption that makes you lose all sense of time. The second is what is known as autotelicity, the sense that the activity you are engaged in is rewarding for its own sake. The third is finding the "sweet spot", a feeling that your skills are perfectly matched to the task at hand, leaving you neither frustrated nor bored. And finally, flow is characterised by automaticity, the sense that "the piano is playing itself", for example.

Exactly what happens in the brain during flow has been of particular interest, but it has been tricky to measure. Csikszentmihalyi took an early stab at it, using electroencephalography (EEG) to measure the brain waves of expert chess players during a game. He found that the most skilled players showed less activity in the prefrontal cortex, which is typically associated with higher cognitive processes such as working memory and verbalisation. That may seem counter-intuitive, but silencing self-critical thoughts might allow more automatic processes to take hold, which would in turn produce that effortless feeling of flow.

Later studies have confirmed these findings and revealed other neural signatures of flow. Chris Berka and her colleagues at Advanced Brain Monitoring in Carlsbad, California, for example, looked at the brain waves of Olympic archers and professional golfers. A few seconds before the archers fired off an arrow or the golfers hit the ball, the team spotted a small increase in what's known as the alpha band, one of the frequencies that arises from the electrical noise of all the brain's neurons (The International Journal of Sport and Society, vol 1, p 87). This surge in alpha waves, Berka says, is associated with reduced activation of the cortex, and is always more obvious in experts than in novices. "We think this represents focused attention on the target, while other sensory inputs are suppressed," says Berka. She found that these mental changes are accompanied by slower breathing and a lower pulse rate – as you might expect from relaxed concentration.

Defining and characterising the flow state is all very well, but could a novice learn to turn off their critical faculties and focus their attention in this way, at will? If so, would it boost performance? Gabriele Wulf, a kinesiologist at the University of Nevada at Las Vegas, helped to answer this question in 1998, when she and her colleagues examined the way certain athletes move (Journal of Motor Behavior, vol 30, p 169).

At the time, she had no particular interest in the flow state. But Wulf and her colleagues found that they could quickly improve a person's abilities by asking them to focus their attention on an external point away from their body. Aspiring skiers who were asked to do slalom-type movements on a simulator, for example, learned faster if they focused on a marked spot ahead of them. Golfers who focused on the swing of the club were about 20 per cent more accurate than those who focused on their own arms.

Wulf and her colleagues later found that an expert's physical actions require fewer muscle movements than those of a beginner – as seen in the tight, spare motions of top-flight athletes. They also experience less mental strain, a lower heart rate and shallower breathing – all characteristics of the flow state (Human Movement Science, vol 29, p 440).

These findings were borne out in later studies of expert and novice swimmers. Novices who concentrated on an external focus – the water's movement around their limbs – showed the same effortless grace as those with more experience, swimming faster and with a more efficient technique. Conversely, when the expert swimmers focused on their limbs, their performance declined (International Journal of Sport Science & Coaching, vol 6, p 99).

Wulf's findings fit well with the idea that flow – and better learning – comes when you turn off conscious thought. "When you have an external focus, you achieve a more automatic type of control," she says. "You don't think about what you are doing, you just focus on the outcome."

Berka has been taking a different approach to evoke the flow state – her group is training novice marksmen to use neurofeedback. Each person is hooked up to electrodes that tease out and display specific brain waves, along with a monitor that measures their heartbeat. By controlling their breathing and learning to deliberately manipulate the waveforms on the screen in front of them, the novices managed to produce the alpha waves characteristic of the flow state. This, in turn, helped them improve their accuracy at hitting the targets. In fact, the time it took to shoot like a pro fell by more than half (The International Journal of Sport and Society, vol 1, p 87).

But as I found when I tried the method, even neurofeedback has a catch. It takes time and effort to produce really thrumming alpha waves. Just when I thought I had achieved them, they evaporated and I lost my concentration. Might there be a faster way to force my brain into flow? The good news is that there, too, the answer appears to be yes.

That is why I'm now allowing Michael Weisend, who works at the Mind Research Network in Albuquerque, New Mexico, to hook my brain up to what's essentially a 9-volt battery. He sticks the anode – the positive pole of the battery – to my temple, and the cathode to my left arm. “You’re going to feel a slight tingle,” he says, and warns me that if I remove an electrode and break the connection, the voltage passing through my brain will blind me for a good few seconds.

Weisend, who is working on a US Defense Advanced Research Projects Agency programme to accelerate learning, has been using this form of transcranial direct current stimulation (tDCS) to cut the time it takes to train snipers. From the electrodes, a 2-milliamp current will run through the part of my brain associated with object recognition – an important skill when visually combing a scene for assailants.

The mild electrical shock is meant to depolarise the neuronal membranes in the region, making the cells more excitable and responsive to inputs. Like many other neuroscientists working with tDCS, Weisend thinks this accelerates formation of new neural pathways during the time that someone practises a skill. The method he is using on me boosted the speed with which wannabe snipers could detect a threat by a factor of 2.3 (Experimental Brain Research, vol 213, p 9).

Mysteriously, however, these long-term changes also seem to be preceded by a feeling that emerges as soon as the current is switched on and is markedly similar to the flow state. “The number one thing I hear people say after tDCS is that time passed unduly fast,” says Weisend. Their movements also seem to become more automatic; they report calm, focused concentration – and their performance improves immediately.

It’s not yet clear why some forms of tDCS should bring about the flow state. After all, if tDCS were solely about writing new memories, it would be hard to explain the improvement that manifests itself as soon as the current begins to flow.

One possibility is that the electrodes somehow reduce activity in the prefrontal cortex – the area used in critical thought, which Csikszentmihalyi had found to be muted during flow. Roy Hamilton, a neuroscientist at the University of Pennsylvania in Philadelphia, thinks this may happen as a side effect of some forms of tDCS. “tDCS might have much more broad effects than we think it does,” he says. He points out that some neurons can mute the signals of other brain cells in their network, so it is possible that stimulating one area of the brain might reduce activity in another.

Uncertain effect

Others are more sceptical. Arne Dietrich of the American University of Beirut, Lebanon, suspects that learning will be impaired if the frontal cortex isn’t initially engaged in the task. What’s more, he thinks you would need a specialised type of tDCS to dampen activity in the prefrontal cortex. “But then again, it is not clear what sort of ripple effect tDCS has globally,” he concedes, “regardless of which brain area is targeted.”

In any case, it is clear that not all forms of tDCS bring about flow. Roi Cohen Kadosh at the University of Oxford certainly saw no signs of it when he placed an anode over the brain regions used in spatial reasoning.

This debate will only be resolved with much more research. For now, I’m intrigued about what I’ll experience as I ask Weisend to turn on the current. Initially, there is a slight tingle, and suddenly my mouth tastes like I've just licked the inside of an aluminium can. I don't notice any other effect. I simply begin to take out attacker after attacker. As twenty of them run at me brandishing their guns, I calmly line up my rifle, take a moment to breathe deeply, and pick off the closest one, before tranquilly assessing my next target.

In what seems like next to no time, I hear a voice call out, "Okay, that's it." The lights come up in the simulation room and one of the assistants at Advanced Brain Monitoring, a young woman just out of university, tentatively enters the darkened room.

In the sudden quiet amid the bodies around me, I was really expecting more assailants, and I'm a bit disappointed when the team begins to remove my electrodes. I look up and wonder if someone wound the clocks forward. Inexplicably, 20 minutes have just passed. "How many did I get?" I ask the assistant.

She looks at me quizzically. "All of them."

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