There are far too many articles on trans-cranial stimulation to post here, but here is a summary of some of the best in abstracts that prove the SCIO/Eductor history of success.
MAGNETIC ELECTRO-ACUPUNCTURE BRAIN STIMULATION

MAGNETIC WAND

Lose Weight with Electro-Shock Therapy

By Douglas Robb on January 29, 2013 @ healthhabits

A new study, published in the journal Obesity and Weight Loss Therapy, has found that cranial electrotherapy stimulation was able to amplify the weight loss effects of both...

Better Living Through Electrochemistry

We can direct the Power of the Cybermagnetic Music or the SCIO/Eductor Energy into an Acupuncture point or into a Brain area

Skill Learning Strategy

Can we accelerate nondeclarative (skill) learning?

- Previous research – enhancement simple motor procedural learning with motor cortex stimulation (Galea & Celnik, 2009)
- Wanted to examine more complex motor procedural task

Strategy

Enhance motor skill Excite – Motor Cortex

Depress competing memory Inhibit – Prefrontal Cortex
Every military application of tDCS I’ve seen so far specifically mentions drones and drone pilot training. This logo has a drone in it! For the record, I think the use of drones is illegal and immoral, and that the deaths of innocents are un-American and unacceptable. That said, the tDCS research coming out of this sector is fascinating and will no doubt have an impact beyond military training.

This comes from https://community.apan.org/afosr/m/bioenergy_program_review/114364.aspx and is a public document (no longer available). It appears to be a set of slides used in a presentation. It documents the most aggressive use of tDCS for the purpose of learning and cognitive enhancement I’ve seen. You will conclude, after reading this that the Air Force is not fooling around.
Here is one of the more shocking aspects of the research: The notion that cathodal stimulation can have a positive effect by depressing ‘competing memory’. What? The plot thickens.

There is weeks of research ahead for anyone diving deeply into this paper. A lot of new questions to answer.
Does Passing A Small Current Through Your Brain Really Make You Smarter?

Posted on January 7, 2013 by John

A lot of the ‘pop sci’ articles are drawing on the results of only a few studies. Hopefully we’ll get affirmation of the efficacy of tDCS in cognitive enhancement soon.

Excellent update from Giulio Ruffini of Neuroelectrics. Full of links to relevant papers.

**tDCS and Stroke: What We Know So Far (Jan 2013)**

As far as I can tell, this is a new development in understanding the mechanism for the mediation of pain using tDCS.

**Immediate effects of tDCS on the μ-opioid system of a chronic pain patient**

To our knowledge, we provide data for the first time in vivo that there is possibly an instant increase of endogenous μ-opioid release during acute motor cortex neuromodulator with tDCS. (And the pop-sci media follow-up [Electrical Current Can Unlock The Seriously Good Drugs In Your Brain and Happiness Is a Warm Transcranial Direct Current Electrode](#))

A lot of research is going on right now into understanding where exactly, current if flowing.

**The electric field in the cortex during transcranial current stimulation**

The aim of this study was to investigate the effect of tissue heterogeneity and of the complex cortical geometry on the electric field distribution.

Some context.

**A pioneer work on electric brain stimulation in psychotic patients. Rudolph Gottfried Arndt and his 1870s studies.**

Today’s brain stimulation methods are commonly traced back historically to surgical brain operations. With this one-sided historical approach it is easy to overlook the fact that non-surgical electrical brain-stimulating applications preceded present-day therapies.

Mental Practice, or MP is practicing doing something without actually doing it. A musician imagining playing their instrument for instance. This study measured quality of handwriting with the non-dominant hand while using tDCS.

**Site-specific effects of mental practice combined with transcranial direct current stimulation on motor learning**
In conclusion, our results suggest that MP-induced effects in improving motor performance can be successfully consolidated by excitatory non-invasive brain stimulation on the M1 and left DLPFC.
Anodal trans-cranial direct current stimulation of prefrontal cortex enhances working memory – Springer

[Update 12/17/2012 Another paper discussing the efficacy of using tDCS to enhance working memory.

Trans-cranial direct current stimulation of the prefrontal cortex modulates working memory performance: combined behavioral and electrophysiological evidence

Working memory, as associated with ‘brain training’ and ‘plasticity’, is often expressed as what one would wish to have more of, or at the very least, what one hopes not to lose as we age. (For a great overview of working memory and the how’s of enhancing it, see this fascinating post from neuroscientist Bradley Voytek’s blog Working memory and cognitive enhancement.)

Our aim was to determine whether anodal transcranial direct current stimulation, which enhances brain cortical excitability and activity, would modify performance in a sequential-letter working memory task when administered to the dorsolateral prefrontal cortex DLPFC. Fifteen subjects underwent a three-back working memory task based on letters. This task was performed during sham and anodal stimulation applied over the left DLPFC. Moreover seven of these subjects performed the same task, but with inverse polarity cathodal stimulation of the left DLPFC and anodal stimulation of the primary motor cortex M1. Our results indicate that only anodal stimulation of the left prefrontal cortex, but not cathodal stimulation of left DLPFC or anodal stimulation of M1, increases the accuracy of the task performance when compared to sham stimulation of the same area. This accuracy enhancement during active stimulation cannot be accounted for by slowed responses, as response times were not changed by stimulation. Our results indicate that left prefrontal anodal stimulation leads to an enhancement of working memory performance. Furthermore, this effect depends on the stimulation polarity and is specific to the site of stimulation. This result may be helpful to develop future interventions aiming at clinical benefits.

via Anodal transcranial direct current stimulation of prefrontal cortex enhances working memory – Springer. full pdf

This 2011 paper does confirm positive results of tDCS in a similar application and test setup. Improving working memory: exploring the effect of transcranial random noise stimulation and transcranial direct current stimulation on the dorsolateral prefrontal cortex.

However, the study does provide confirmation of previous findings that anodal tDCS enhances some aspects of DLPFC functioning.
PLOS ONE: Trans-cranial Direct Current Stimulation Augments Perceptual Sensitivity + 24-Hour Retention in a Complex Threat Detection Task

Posted on December 9, 2012 by John Vincent Clark is an author on this paper. He’s associated with the Mind Research Network. We earlier covered work by Michael Weisend, also from MRN around a Jan. 2012 paper. This paper offers further details and is available to the public.

Trans-cranial Direct Current Stimulation Procedures

TDCS was applied using an ActivaDose II Iontophoresis Delivery Unit, which provides for delivery of a constant low level of direct current. Square-shaped (11 cm$^2$) saline-soaked (0.9% sodium saline solution) sponge electrodes were attached to the participant with self-adhesive bandage strips. The anode was placed near electrode site F10 in the 10-10 EEG system, over the right sphenoid bone. The cathode was placed on the contralateral (left) upper arm. The site of the anode was selected based on our previous fMRI results showing that this brain region was the primary locus of neural activity associated with performance this task [23].

Anodal 2 mA current was applied to the scalp electrode site F10 in the 10-10 EEG system. The resulting enhancement of performance in the threat detection task is consistent with our previous fMRI results [23] showing that the right inferior frontal cortex is a major locus of a distributed brain network that mediates performance on this task. The right parietal cortex is a part of this network and could also be a target for stimulation.

One possible explanation for the improvement in detection performance (hit rate) in the threat detection task is that tDCS increases general arousal, thereby leading to a change in response bias in the more liberal direction [25], which would increase the hit rate. However, computation of signal detection metrics showed that there were no significant effects of tDCS on the β measure of response bias. Instead, the effect of brain stimulation was to enhance perceptual sensitivity, $d'$. The improvement in perceptual sensitivity suggests that participants receiving tDCS were better able to encode stimulus features that distinguished targets and non-targets, which in turn led to accelerated learning and improved retention.

tDCS – Building Research tDCS Units « SpeakWisdom

Posted on November 19, 2012 by John

This bubbled up today. He explores some choices he made in building his DIY kit in a series of blog posts on tDCS.

*Just to see how easily it could be done, I built a couple of tDCS units for about $30 each using common parts. The meters were purchased from EBay for about $7 each and all the remaining components came from a local Radio Shack, including the case, voltage regulator, resistors, etc. The tDCS units feature a potentiometer to make it possible to adjust current for treatment specifics or pad variations.*

*(Two tDCS units built in about 3 hours for well less than $100)*

Trans-cranial Direct Current Stimulation Intensity and Duration Effects on Tinnitus Suppression

Posted on October 6, 2012 by John

Tinnitus has been a part of my life for so long I can’t remember not having it. While it doesn’t seem to bother me the way it does others, it can be very annoying, especially when I’m in a very quiet environment, camping for instance. So it would be incredible if a breakthrough in tinnitus treatment were to come along.
Background. Perception of sound in the absence of an external auditory source is called tinnitus, which may negatively affect quality of life. Anodal transcranial direct current stimulation tDCS of the left temporoparietal area LTA was explored for tinnitus relief. Objective. This pilot study examined tDCS dose current intensity and duration and response effects for tinnitus suppression. Methods. Twenty-five participants with chronic tinnitus and a mean age of 54 years took part. Anodal tDCS of LTA was carried out. Current intensity 1 mA and 2 mA and duration 10 minutes, 15 minutes, and 20 minutes were varied and their impact on tinnitus measured. Results. tDCS was well tolerated. Fifty-six percent of participants 14 experienced transient suppression of tinnitus, and 44% of participants 11 experienced long-term improvement of symptoms overnight—less annoyance, more relaxed, and better sleep. There was an interaction between duration and intensity of the stimulus on the change in rated loudness of tinnitus, $F_2, 48 = 4.355, P = .018$, and clinical global improvement score, $F_2, 48 = 3.193, P = .050$, after stimulation. Conclusions. Current intensity of 2 mA for 20 minutes was the more effective stimulus parameter for anodal tDCS of LTA. tDCS can be a potential clinical tool for reduction of tinnitus, although longer term trials are needed.

Where To Find More Information

I’m calling this the deep data page. I’ll collect links to collections of papers and abstracts that cover tDCS. There is really, a LOT, of information out there and lots more is on the way. I’ll update this page as I come across more articles. If you have a favorite tDCS stash, please share it in the comments.

- Soterix Medical has an excellent collection of tDCS Abstracts it keeps updated.
- Growing.com has a great collection of tDCS related Abstracts, and an extensive collection of full articles.
- MIT Press links to tDCS abstracts.
- PubMeb tDCS search return over 600 articles.
- Some very interesting tDCS articles from MusiciansBrain.com.
- Hundreds of results at Google Scholar.
- Trans-Cranial Technologies has a great list of tDCS abstracts.

Vincent Walsh TMS > tDCS & Migraine

Towards the end of the video (The Daily Telegraph 2008) Professor Vincent Walsh, (now of University of California Davis) discusses tDCS and its potential for therapeutic use. Especially of interest is the information on migraine headaches:
So, some migraines are caused by having too much activity in the visual brain area, and some are by having too little activity. And we hope that this can balance out, reverse that relative inactivity in the brain.

Could this imply that one person’s migraine could be mitigated with Cathodal (-) tDCs while another’s might benefit from Anodal (+) application of tDCS? And conversely, does it imply that improper stimulation would lead to MORE migraines?

If I suffered from migraines and wanted to test tDCS, here’s where I’d start:
Check the FisherWallace Find A Doctor search page for an electrotherapist in your area.
If they will treat you for migraine, try a few sessions. If it works, and your doctor will authorize a purchase, you can buy your own unit (for $700). A FisherWallace device may qualify for insurance coverage.
Alternately, I would monitor the ClinicalTrials.gov site and keep an eye out for new studies testing tDCS for migraine. And lastly, I would contact manufacturers of other tDCS devices and ask if they knew of any electrotherapy practitioners in your area working with migraine. Here’s my short list of manufacturers to contact:

- **Soterix Medical**: Are on the cutting edge of all things tDCS and in some of their literature I have seen them mention migraine.
- **MagStim**: Another medical-level producer, although I’m not sure these devices are approved for use in the U.S. yet.
- **Alpha-Stim**: While they don’t advertize the use of their device for migraine, they do offer many testimonials from people who state they found it beneficial. I have not seen this company associated with any scientific studies or papers.

**Induction of visual dream reports after trans-cranial direct current stimulation (tDCs) during Stage 2 sleep – JAKOBSON – 2012 – Journal of Sleep Research**

This is encouraging because a previous study showed minimal effect on dreaming using tDCS.

*In both experiments a significantly greater number of imagery reports were found on awakening after tDCs (cathodal–frontal, anodal–parietal), compared to the blank control conditions. However, in Experiment 2 the frequency of imagery reports from the tDCs (cathodal–frontal, anodal–parietal) was not significantly different from the other two tDC conditions, suggesting a non-specific effect of tDCs. Overall, it was concluded that tDCs (cathodal–frontal, anodal–parietal) increased the frequency of dream reports with visual imagery, possibly via a general arousing effect and/or recreating specific cortical neural activity involved in dreaming.*
Amping Up Brain Function:
Trans-cranial Stimulation Shows Promise in Speeding up Learning:
Scientific American

Another group of researchers hot on the trail how tDCS might be used to enhance brain function is the (non-profit) Mind Research Network of Albuquerque, NM. A lot of their work is funded by NiH, but what I’ve seen around their tDCS research pertains to increasing soldier’s ability to detect danger, and is funded by DOA (2010 Research Report pdf) Unfortunately I was not able to find a full version of the paper not behind a pay wall. The abstract is here and from a Scientific America article…

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.

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.

A multifunctional on-line brain stimulation system

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and

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A flexible on-line electrical brain stimulation system designed for brain stimulation reward (BSR) research is described. A Cromemco Z-2D microcomputer is interfaced with a constant-current stimulator and a standard operant chamber. The system programs, written substantially in BASIC, calculate BSR threshold by two rate-independent methods, measure rate of operant responding, and determine resistance of the brain. Other software programs are used for training rate on complex schedules of reinforcement, for system hardware calibration, and for sophisticated statistical data analyses.

Using a classical psychophysical technique to measure electrical brain stimulation reward (BSR) thresholds presents a significant problem. The subject's behavior (usually leverpressing) is controlled by the reinforcing stimulation for which the threshold is to be found. Many experimenters have tried to avoid this problem by measuring animal response rate using suprathreshold stimulation and inferring changes in threshold from changes in rate. If a rate measure is used, however, it is not possible to discriminate between the effects of the experimental treatment on threshold vs. its effects on motor responses.

Alternative methods (Huston & Mills, 1971; Marcus & Kornetsky, 1974; Valenstein & Meyers, 1964) determine threshold with less reliance on rate of response. Huston and Mills (1971) measure BSR threshold with a psychophysical procedure based on the observation that performance under a fixed-ratio (FR) schedule is different from that under a continuous reinforcement (CRF) schedule (Ferster & Skinner, 1957). In this procedure, rats leverpress for rewarding stimulation on an FR schedule and, concurrently, on a CRF schedule, using a single lever. This combined schedule is known as a CRF-FR. The FR current intensity is fixed at a suprathreshold level, which maintains the leverpressing response at any CRF current intensity.

An animal performing on a "pure" FR schedule exhibits postreinforcement pauses (PRPs) (Ferster & Skinner, 1957). As CRF current intensity is increased from zero on a CRF-FR schedule, FR pauses become shorter and eventually disappear. The rat's performance shifts from that which is characteristic of an FR schedule (many PRPs) to that which is characteristic of a CRF schedule (no PRPs). Decreasing the CRF current intensity causes the pauses to reappear. Threshold is determined by appearance or disappearance of these pauses as the CRF current intensity is varied. Huston and Mills (1971) reported that threshold determination was independent of the size of the FR and of the suprathreshold FR current intensity.

The definition of a PRP has been a problem using this threshold technique. Huston (Note 1) defined a PRP as the interval just visually discernible on the cumulative recorder. Cassens and Mills (1973) defined it as an interval greater than 7 sec, but not more than 3 min. Cassens, Shaw, Dudding, and Mills (1975) devised a rate-dependent definition: A PRP was defined as an interval greater than the mean CRF interresponse interval (IRI) plus three standard deviations. Thus, a PRP was relative to the CRF IRI. This provided a rate-independent means of determining the PRP and, hence, threshold.

The system presented in this paper employs the same rate-independent concept for determining threshold. A fixed number of FR reinforcements are presented at each CRF current level. Threshold is defined as the current level that produces PRPs half of the time, that is, a PRP/FR ratio of .50. Threshold is determined by evaluating PRP/FR ratios over a CRF current range, and then interpolating the current value at a PRP/FR of .50 (see Figure 1).

Threshold determination using this system is reliable
Mapping of woman’s brain reveal new regions of sexual stimulation

For the first time, researchers have shown that the stimulation of the vagina, cervix and clitoris activate three separate regions in the sensory cortex of a woman's brain, contrary to what many sex experts have long believed.

By: Debra Black  Staff Reporter, Published on Thu Nov 24 2011

For the first time, the stimulation of the vagina, cervix and clitoris are shown to activate three separate regions in the sensory cortex of a woman’s brain.

The discovery comes from Barry Komisaruk, a psychology professor at Rutgers University, who has spent considerable time mapping the brain and how it is activated during sexual stimulation and orgasm. Komisaruk and his team recently presented an animated video of a woman’s brain as she reaches orgasm using brain scan images.

In a study published earlier this year in the Journal of Sexual Medicine, Komisaruk was able to map a series of women’s brains using functional magnetic resonance imaging to see whether or not stimulation of the vagina and cervix would activate any regions of the brain.
Eleven women, ages 23-56, participated in the study and had their brains mapped as they engaged in self-stimulation.

The sensory regions of the brain were first mapped by Montreal neurosurgeon Wilder Penfield in the 1950s on male epilepsy patients. It was called the sensory homunculus and detailed a man’s body parts and their corresponding sensory regions in the brain.

What Komisaruk found changes the way many think about the way women are sexually stimulated and how it affects their brains.

Many sex experts have said and believed that genital stimulation came from the stimulation of the clitoris as compared to the vagina and cervix.

“What we show is that each of those three regions produce a significant sensory input to the cortex,” explained Komisaruk.

“There had been some controversy in the literature as to whether the vagina and cervix produce a sensory response,” he said. “This is clear evidence they do.”

“This was a big surprise to my male neuroscience colleagues because it violates the classical view of the sensory mapping of the body.”

Another unexpected result of the study was that nipple stimulation not only shows up in the chest area of the brain, but also in the genital area.

This could explain why nipple or breast stimulation is erotic, said Komisaruk.

The study is “clear evidence that there is a sensory response from the vagina and cervix” — something many have denied.

The parts of the brain that are activated when the vagina and cervix are stimulated are very near the spot in the brain which is activated when a woman’s clitoris is stimulated.

“They’re clustered together like three grapes,” said Komisaruk. “They each have a distinct projection zone and clearly are different from each other yet clustered together in the sensory cortex.”

And they are in the same general area of the sensory cortex which is stimulated in a man when his genitals are stimulated, he said.

Komisaruk and others believe that by understanding how stimulation of different female genital regions effect the brain and how they interrelate will help researchers understand women’s sexuality and perhaps provide answers to sexual dysfunction.
Amping Up Brain Function: Transcranial Stimulation Shows Promise in Speeding Up Learning

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

Nov 25, 2011 | By R. Douglas Fields

Courtesy of Richard A. McKinley, USAF
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.

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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.

Cranial Electrotherapy Stimulation: A Non-Drug Neuromedical Treatment

By Eileen Jones, RN, MPH | 30 Comments | Share | Print | Email | Tweet | Like | 1+

Cranial electrotherapy stimulation (CES), (also known as “electrosleep”, “transcranial electrotherapy” and by many other names), involves a form of treatment that sends low intensity microcurrent (under 1 milliampere) to the brain. [1] CES devices function differently from other biomedical electronics, such as deep brain stimulating electrodes (which prevent seizures and hand tremors) [2] and heart pacemakers. While those instruments require surgical implantation, CES operates non-invasively. Designed for home use, the devices deliver current to the brain via a hand held machine to electrodes attached on or behind the ears. [3]

Uses for Brain Health
A wide body of research suggests that the technique effectively treats insomnia, depression and anxiety (the only FDA approved uses). Scientific data also shows promise for other conditions such as pain, tension/migraine headaches, fibromyalgia, and ADHD. CES might also provide benefits for chemical dependencies (such as street and prescription drugs, alcohol, and tobacco); that is, it might help the insomnia, anxiety and depression that often manifest during withdrawal. [4,5]

Patient Experience
The devices, sold by prescription in the U.S., require initial assessment and ongoing medical follow-up. [6] Treatment protocols vary based upon the health issue and the phase of treatment. Therefore, patients with anxiety typically use devices for 20-60 minutes daily for the first 2 to 3 weeks, with less frequent use thereafter. [7] Users may do other things during treatment (such as read, watch TV), but should not drive or operate machinery during or shortly after treatment. [8]

Individual responses may vary, but most users report reduced symptoms (such as anxiety) after their first or second treatment. Severe depression however, may require three weeks for therapeutic results. During use, patients often experience pleasant mental states with increased muscle relaxation yet enhanced mental clarity. They might also feel a pulsing or tingling sensation in their earlobes, (considered normal), which setting adjustments can alleviate. Positive effects after a single treatment may last up to two days and effects usually become cumulative. [9]

**Brain Effects**

Researchers don’t fully understand mechanisms involved, but theorize that CES electrical current helps reestablish optimal brain chemistry and improves efficiency of neural connections. [10] One example of research supporting this theory involves electrical engineering simulations conducted by researchers at the University of Texas, Austin. Their brain mapping techniques suggested that minute amounts of current traveled to the brain’s thalamus, enough to enable release of neurotransmitters. [11] Other research conducted by North Dakota State University utilized EEG techniques to quantify changes during administration of CES versus sham treatment. The research showed frequency distribution shifts suggestive of beneficial changes. [12]

Based on current and ongoing research, neuroscientist Dr. James Giordano postulates that CES microcurrent travels to the base of the brain (the brainstem), activating clusters of nerve cells which make the brain chemicals serotonin and acetylcholine. Serotonin is linked to relaxation [13] while acetylcholine is linked to body processes not under conscious control while at rest. [14] Released by nerve cells at the synapse, these neurotransmitters influence pathways within the brain and spinal cord that inhibit arousal and agitation. The resulting “fine tuning” helps the nervous system to restore homeostatic balance and possibly creates brain patterns known as alpha rhythms. Measurable via brain wave recordings (called EEG); scientists often associate alpha states with enhanced mental focus and relaxation. Neurological processes linked to alpha states seem to reduce stress, stabilize mood, and exert control over certain types of pain.

**Effectiveness**

Scientists conducted much of the early work on CES in France. Starting work in the early 1900’s, they theorized that minute amounts of current (applied to the head) would calm the
central nervous system, inducing a sleep-like state. [16] The technique took hold in the West in the late 1960’s, when Austria hosted International Symposia on the topic. The uneven quality of studies published up until that time however, generated skepticism as well as further research. Still in progress, the scientific community has accumulated years of research, which spans the past century. [17]

In his recently revised book, The Science Behind Cranial Electrotherapy Stimulation, Daniel L. Kirsch reviewed CES research from the last 40 years which includes 126 human and 29 animal studies, and 31 review articles. Over half came from peer-reviewed sources and most, coming from major US universities used double blind techniques. Of studies reviewed, 112 (89%), claimed positive results. Seventeen follow-up studies evaluating residual effects (lasting 1 week to 2 years) showed at least some continuing effect in all of the patients. [18]

While a body of published research does exist, some have reservations. Research design and quality varies widely and very few peer reviewed journals are publishing recent studies. Complicating matters, makers of the device often lack proper funding to support high quality research. [19] Others think the technique needs more study in terms of practicality and cost effectiveness. [20]

As a way to clarify CES efficacy, medical researchers from the Harvard School of Public Health published a thorough scientific review of CES devices. Their report identified 18 of the most rigorous studies of CES versus sham treatment. They then applied meta-analysis to 14 of those studies, using combined results to further discern effects after treating four different conditions. [21] Reconfirming previous meta-analysis by University of Tulsa researchers, [22] pooling techniques showed CES to be significantly more effective for treating anxiety; but they did not affect results for insomnia, headache, and brain dysfunction. The review team made comment that most studies under scrutiny needed to publish more complete data and blind treatment providers from knowing which patients were getting CES. [23]

**Safety/Precautions**

CES has an excellent safety record, few side-effects, and works well for all age groups. CES users sometimes have temporary headaches, lightheadedness, skin irritation from electrodes and rare paradoxical reactions (such as excitement, anxiety, sleep problems, or increases in pre-existing depression). Pregnant or lactating women, people with implanted bioelectrical devices, or those taking supplements or medications affecting the brain or vascular system should first consult with a physician. [24] Of 17 follow-up studies conducted up to two years after treatment, none showed negative effects. [25] Very few major short or long-term problems have therefore been found, and several of the devices carry FDA approval. [26]

**Implications for Use**

CES has been around for many years, yet its use in the U.S. remains little known. First of all, new therapies must prove efficacy to gain recognition. [27] Additionally, medical school training
is non-existent, postgraduate continuing education offerings are scarce, and device makers lack marketing resources. [28] Given that mainstream providers and the public seem mostly unaware of the treatment, alternative providers may be prescribing it most. Among the few who do know about CES, opinions vary. According to Dr. Daniel Kirsch, an authority on electromedicine and Chairman of Electromedical Products International, research shows CES to be safe, having good results for a range of brain based disorders. He believes the evidence supports use as a first line treatment for issues it effectively treats. [29]

Upon their review, insurer Aetna however, found that CES remains “experimental and investigational” for major depression, other psychiatric disorders, and for “neuropsychological indications (alcoholism, chemical dependency, dementia, depression, headache)...” They say that the evidence is encouraging, yet the issue needs more study. [30]

According to distributor Elixa Peak Performance, CES works best as a treatment (not a cure) for the anxiety, insomnia and depression that comes as a byproduct of stress. But the web site also suggests that it can treat a number of other stress related disorders as well as boost IQ and peak performance. [31]

In contrast, physician Dr. Stephen Barret of Quackwatch takes issue with those who claim benefits beyond approved uses or distributors who sell devices with commercial nutritional programs. He does concede that CES has shown effectiveness for anxiety and possible other uses. But he then points out that physicians, naturopaths or chiropractors (who prescribe CES most) might not be qualified to diagnose and treat neuropsychological problems. He further states that it’s better to get to the root of a problem than only treat symptoms. [32]

Writing on behalf of the Houston VA Pain Management Program, psychologists Dr. Gabriel Tan and Dr. Julie Alvarez argue for integrating CES and self hypnosis into multidisciplinary pain treatment programs. Clinic patients usually have intense chronic pain, not helped by analgesics; additionally, they often travel long distances for treatment, having limited means, and social problems. Seeing pain mainly as a physical problem and lacking resources for long treatments, patients often want tangible, fast results. CES and self hypnosis combined therefore meet the need, as they take little time and provide quick results. After getting some measure of relief, patients are often more willing to accept additional psychological help as a part of their treatment plan. [33]

Physician advocates Dr. Marshall F. Gilula and Dr. Paul Barach (in an editorial published by Southern Medical Journal) assert that the device can be a valuable treatment for the approved uses of anxiety, depression, and insomnia. While physicians usually treat those problems with psychoactive drugs, they point out that the medications often pose safety concerns; that is, they have potential for side-effects or dependency. [34] (FDA warnings for selective serotonin reuptake inhibitors used for depression, serve as a prime example.) [35] Like psychoactive drugs, CES does require ongoing medical supervision, but it doesn’t have the same potential for problems. Ultimately, they maintain that CES is of great value as a safe, non-drug
alternative which can reduce or sometimes even replace medication use. They say that while CES is not a miracle cure, it is at least worthy of consideration. [36]

References


24. Elixa Peak Being. Cranial electrical stimulation (CES) for neurotransmitter balancing, mood control, IQ gains, sleep, exploration of altered states, peak performance, and much more. Elixa


27. Collins WG. Book review: the science behind cranial electrotherapy stimulation. 
NeuroRehabilitation. 2000; 2:123.


A novel transcutaneous vagus nerve stimulation leads to brainstem and cerebral activations measured by functional MRI.

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Author information

Abstract

BACKGROUND:
Left cervical vagus nerve stimulation (VNS) using the implanted NeuroCybernetic Prosthesis (NCP) can reduce epileptic seizures and has recently been shown to give promising results for treating therapy-resistant depression. To address a disadvantage of this state-of-the-art VNS device, the use of an alternative transcutaneous electrical nerve stimulation technique, designed for muscular stimulation, was studied. Functional magnetic resonance imaging (MRI) has been used to test non-invasively access nerve structures associated with the vagus nerve system. The results and their impact are unsatisfying due to missing brainstem activations. These activations, however, are mandatory for reasoning, higher subcortical and cortical activations of vagus nerve structures. The objective of this study was to test a new parameter setting and a novel device for performing specific (well-controlled) transcutaneous VNS (tVNS) at the inner side of the tragus. This paper shows the feasibility of these and their potential for brainstem and cerebral activations as measured by blood oxygenation level dependent functional MRI (BOLD fMRI).

MATERIALS AND METHODS:
In total, four healthy male adults were scanned inside a 1.5-Tesla MR scanner while undergoing tVNS at the left tragus. We ensured that our newly developed tVNS stimulator was adapted to be an MR-safe stimulation device. In the experiment, cortical and brainstem representations during tVNS were compared to a baseline.

RESULTS:
A positive BOLD response was detected during stimulation in brain areas associated with higher order relay nuclei of vagal afferent pathways, respectively the left locus coeruleus, the thalamus (left >> right), the left prefrontal cortex, the right and the left postcentral gyrus, the left posterior cingulated gyrus and the left insula. Deactivations were found in the right nucleus accumbens and the right cerebellar hemisphere.

CONCLUSION:
The method and device are feasible and appropriate for accessing cerebral vagus nerve structures, respectively. As functional patterns share features with fMRI BOLD, the effects previously studied with the NCP are discussed and new possibilities of tVNS are hypothesised.
Migraine patients find pain relief in electrical brain stimulation

Migraine patients find pain relief in electrical brain stimulation

This is not something new to the treatment of pain at all (Immediate effects of tDCS on the μ-opioid system of a chronic pain patient) and has in fact been used for all sorts of chronic pain from fibromyalgia to neuropathic to pain from chronic injury. The idea being to find the location in the brain that has been rewired by pain, pulse in this electrical current, and the areas can be in effect changed to respond differently over the treatment period. For certain types of injuries the research has been promising and it will be interesting to see if it can be useful in conditions where more areas of the brain are being stimulated and affected, such as migraines... the area being stimulated that seems to help with this treatment is the motor cortex.
Researchers from the University of Michigan School of Dentistry, Harvard University and the City College of the City University of New York used a noninvasive method called transcranial direct current stimulation (tDCS) as a preventative migraine therapy on 13 patients with chronic migraine, or at least 15 attacks a month. After 10 sessions, participants reported an average 37 percent decrease in pain intensity.

The effects were cumulative and kicked in after about four weeks of treatment, said Alexandre DaSilva, assistant professor at the U-M School of Dentistry and lead author of the study, which appears in the journal Headache.

"This suggests that repetitive sessions are necessary to revert ingrained changes in the brain related to chronic migraine suffering," DaSilva said, adding that study participants had an average history of almost 30 years of migraine attacks.

The researchers also tracked the electric current flow through the brain to learn how the therapy affected different regions.

"We went beyond, 'OK, this works,'" DaSilva said. "We also showed what possible areas of the brain are affected by the therapy."

They did this by using a high-resolution computational model. They correctly predicted that the electric current would go where directed by the electrodes placed on the subject's head, but the current also flowed through other critical regions of the brain associated with how we perceive and modulate pain.

"Previously, it was thought that the electric current would only go into the most superficial areas of the cortex," DaSilva said. "We found that pain-related areas very deep in the brain could be targeted."

Other studies have shown that stimulation of the motor cortex reduces chronic pain. However, this study provided the first known mechanistic evidence that tDCS of the motor cortex might work as an ongoing preventive therapy in complex, chronic migraine cases, where attacks are more frequent and resilient to conventional treatments, DaSilva said.

While the results are encouraging, any clinical application is a long way off, DaSilva said.

"This is a preliminary report," he said. "With further research, noninvasive motor cortex stimulation can be in the future of adjuvant therapy for chronic migraine and other chronic pain disorders by recruiting our own brain analgesic resources."
Online brainmapping

Some brainmapping terminologies

◆ Absolute power

This refers to the amount of activity within a specific frequency band of brain waves. It is the mean amplitude in a given frequency band. Activity in each frequency band is compared to a normative database to determine the presence of suspected abnormalities. The results for each frequency band are shown with the topographic activity maps. Green is the color representing average activity. Red means there is a large increase in activity when compared to the normative database, while blue means there is a large decrease. In all frequency bands, the absolute power is maximum posteriorly.

◆ Relative power, % Activity

This refers to the relative amount of activity within a specific frequency band compared to all the other frequency bands. Relative activity in each frequency band is compared to a normative database to determine the presence of suspected abnormalities. The results for each frequency band are shown with the topographic activity maps. Green is the color representing average activity. Red means there is a large increase in activity when compared to the normative database, while blue means there is a large decrease.

◆ Coherence

This refers to the similarity in EEG waves over different areas of the brain—i.e., the timing of activity in one area compared to another. Coherence in each frequency band is compared to a normative database to determine the presence of suspected abnormalities. The results for each frequency band are shown with the topographic connection maps. Thick lines represent larger deviations from ‘normal’—red refers to increased coherence, while blue refers to decreased coherence.

◆ Symmetry

This refers to the relationship between the amount of activity in one area of the brain compared to another. Interhemispheric means differences between each side of the brain, while intrahemispheric means differences between areas on the same side of the brain.

Asymmetry in each frequency band is compared to a normative database to determine the presence of suspected abnormalities. The results for each frequency band are shown with the topographic connection maps. Thick lines represent larger deviations from ‘normal’—red refers to increased asymmetry, while blue refers to decreased asymmetry.
We use both sides

BUSINESS BRAIN MAPPING
DON'T BE MISTaken, DON'T BE MISLED, IT'S NOT IN YOUR HEART, IT'S ALL IN YOUR HEAD
The processing of internally-generated interoceptive sensation
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INTRODUCTION
The capacity to engage in mental imagery is a powerful quality of human cognition. It enables an individual to consider information outside the scope of the current environment and in a critical component of both past recollection and future projection (Buckner & Wheeler, 2001). Many individual sensory modalities of mental imagery have been investigated, including visual, auditory, olfactory, somatosensory, and motor imagery (Koskiya, Guis, & Thompson, 2001). However, a prominent omission from previous research has been the visualization of internal state sensations, or interoceptive imagery. While an increasing amount of evidence points to the insula as the primary cortical representation of internal state (Craig, 2004; Critchley, Mathias, & Dolan 2001) there have been no studies investigating its function outside the current environmental context. The goal of this study was to examine the role of the insula during interoceptive imagery.

METHODS
Subjects. Nineteen adults (mean age = 28.1, 13 female) participated in the study. All subjects provided informed consent and were compensated for their time.

Task. Each participant was directed to visualize, as clearly as possible, either an everyday motor action or an internal state sensation described by a text phrase. For each phrase, they were encouraged to make the experience as ‘real and vivid’ as possible. If the phrase was for an everyday motor action they were instructed to visualize themselves doing the action from a first-person perspective. If the phrase was for an internal state sensation they were encouraged to literally ‘feel’ their body in that state. Examples of internal state phrases used in the study were “freezing cold”, “upset stomach” and ‘itchy skin’.

Design. Each subject completed two fMRI runs containing six blocks of each condition. Within each block the subject was presented with a cue to alert them to the visualization condition and then three words from either the internal or action visualization condition. Total scan time for this task was 10 minutes.

Preprocessing. Image processing was completed using SPM8. Preprocessing steps for the functional imaging data included a 6-parameter rigid-body affine realignment of the EPI time-series, unwarping to reduce the influence of movement-induced variance, coregistration of the data to a T₁-weighted anatomical image, and 8 mm full-width at half-maximum (FWHM) Gaussian smoothing.

Analysis. A two-level mixed effects methodology was used. The first level was completed on each subject’s data individually using restricted maximum likelihood estimation of the general linear model. Hemodynamic responses were modeled by a boxcar function convolved with a canonical hemodynamic response. A high pass filter with a frequency cutoff of 1/128 seconds was used to remove low frequency drift in the data. The resulting beta estimates for each subject were then entered into a second-level statistical test to compare the final 2x2 ANOVA.

DISCUSSION
The results of this experiment demonstrate that interoceptive imagery involves the use of cortical structures necessary for the processing of realtime internal state sensations. Differences in BOLD signal were observed in the modality-specific areas that give rise to the unique sensory qualities of each visualization condition. For the visualization of internal state sensations this meant increased activity in areas of interoceptive sensory processing, including the mid and anterior insula in the right hemisphere. This is a critical finding, as it suggests that primary interoceptive cortex, located in the posterior insula, was not significantly involved in the imagery of internal state sensations.

REFERENCES
ORIGINAL ARTICLE

A Comparison of Brain Activity between Healthy Subjects and Stroke Patients on fMRI by Acupuncture Stimulation

Seung-Yeon Cho1, Mei Kim1, Jong Joo Sun1, Geon-Ho Jeong2, Hengjun J Kim3, Seong-Uk Park4, Woo-Sang Jung1, Chang-Nam Ko3, and Jung-Mi Park4

ABSTRACT  Objective: To investigate brain activity patterns during acupuncture in stroke patients, and to compare the results with normal subjects using functional magnetic resonance imaging (fMRI). Methods: A total of 11 stroke patients with motor weakness and 10 healthy subjects were studied. fMRI was performed during acupuncture on the left side at points Quchi (LI11) and Zuazhong (ST36). Data were analyzed using statistical parametric maps of brain activation induced by acupuncture stimulation. Results: The results showed that stimulation of both LI11 and ST36 produced significantly different brain activation patterns between the two groups. The normal group showed a greater overall activation than the stroke group. In the normal group, parts of the frontal lobe, parietal lobe, sub-cortex, cerebellum, and midbrain regions were activated by acupuncture at the left LI11. On the other hand, the right side of the inferior parietal lobe and occipital lobe was activated in the stroke patients. When the left ST36 was stimulated in the normal group, both sides of the frontal lobe, parietal lobe, temporal lobe, and sub-cortex, and the left side of occipital lobe, and the right side of cerebellum and midbrain regions were activated. For the same stimulation in the stroke group, only both sides of the inferior parietal lobe and cerebellum regions were activated (P<0.05, cluster level). Deactivation pattern was not noted during any acupuncture stimulation in both groups. Conclusion: Brain signal activations during the same acupuncture were different between the healthy and the stroke patients, and the results showed a correlation of different acupuncture points.

KEYWORDS  acupuncture, functional magnetic resonance imaging, stroke, LI11, ST36, basal ganglia

Acupuncture has been used to treat stroke for thousands of years. There has been much research done on the effectiveness of acupuncture in stroke recovery and has shown positive conclusions in some clinical trials.1-10 Most of previous functional magnetic resonance imaging (fMRI) studies related to acupuncture suggest that stimulation of specific points activated certain brain areas.11-16 The theory for point specificity of acupuncture is supported by several recent fMRI studies.11-14 However, when acupuncturists treat patients, they usually regard the condition of each individual patient rather than using a standard protocol; even if acupuncture is applied at the same points in different individuals, the effect may be different. However, several acupuncture studies are in progress with healthy subjects and patients, therefore, it is necessary to compare the results of the same treatment between healthy subjects and patients.17-15,16

The acupuncture points Quchi (LI11) and Zuazhong (ST36) are frequently used in stroke patients. These points are often useful in the treatment of both hemiplegia and rehabilitation for motor functional impairment after stroke.

The objective of this study was to investigate brain activity patterns during acupuncture stimulation in stroke patients with basal ganglia infarction, and to compare areas that were activated in stroke patients and in normal subjects. The hypothesis underlying this study was that the same acupuncture may have a different effect on stroke patients than it does on healthy controls.

METHODS

Subjects

A total of 10 healthy, right-handed volunteers (5
Social Faculties in Phrenology

Spurzheim (1834)

1. Destructiveness
2. Amativeness
3. Philoprogenitiveness
4. Adhesiveness
5. Inhabitiveness
6. Combativeness
7. Secretiveness
8. Acquisitiveness
9. Cautiousness
10. Approbativeness
11. Self-Esteem
12. Benevolence
13. Veneration
14. Conscientiousness
15. Hope
16. Mirthfulness
17. Imitativeness
18. Individuality
19. Language
20. Causality
Brain Wave Measurement and Frequencies of Healers

The fact that the brain emits measurable frequencies has been known since the beginning of the last century. In the 1960s, it was discovered that a person could exert some control over these frequencies and the term “biofeedback” was coined to describe this process. With the advent of increased computing power and a deeper understanding of the brain, the research focus is now on “neurofeedback.” The year 2010 saw the first hard evidence of neuroplastic changes occurring directly in the brain after voluntary control of brain rhythms. (T. Ros et al., *Endogenous control of waking brain rhythms induces neuroplasticity in humans*)
The range of brain frequencies has been divided up and named as follows:

- Delta (0 to 4 Hz) – deep nighttime sleep
- Theta (4 to 7 Hz) – dreams at night and trance state of somnambulism
- Alpha (8 to 12 Hz) – background brain activity in the waking state. (Named alpha because it was the first one discovered by Hans Berger in 1908.)
- Beta (12 to 30 Hz) – awake, alert, focused
- Gamma (30 to 100 Hz) – certain cognitive or motor functions

The diagrams below are a 3D representation of brain wave patterns recorded using an IBVA recorder. Across the width of the diagram is the frequency from delta on the left to gamma on the right. Time is recorded in the length of the strip – each diagram being about a five-minute segment of time. Amplitude is shown in the height in microvolts.

The first diagram is that of a client in a non-focused state and shows a random distribution across the ranges. The second diagram shows the coherence and specificity in Jack’s brain as he works with the Reconnective Healing® energy frequencies. The left and right hemispheres of the brain appear in separate windows. The left window represents the left hemisphere of the person. Recordings made in September 2010.
Note: These EEG ( Electroencephalography ) experiments were done by Jean-Charles Chabot, a hypnotherapist specialized in Life Between Lives spiritual hypnosis, who uses the IBVA recorder in his practice. ( www.life-between-lives.ca ).

Note: Jean-Charles and I carried out these experiments without knowing whether such an experiment had been done before. On October 29, 2012, reading Ervin Laszlo's Science and the Akashic Field, ( p. 152-153 ) I discovered a description of a similar experiment showing the same result and giving a bit more information about the condition. Laszlo's book was first published in 2004, a new edition appeared in 2007 both from Inner Traditions in Vermont.

"An experiment carried out in the presence of this writer took place in southern Germany in the spring of 2001. At a seminar attended by about a hundred people, Dr. Günter Haffelder, head of the Institute for Communication and Brain Research of Stuttgart, measured the EEG patterns of Dr. Maria Sági, a trained psychologist and gifted natural healer, together with that of a young man who volunteered from among the participants. The young man remained in the seminar hall while the healer was taken to a separate room. Both the healer and the young man were wired with electrodes, and their EEG patterns were projected on a large screen in the hall. The healer diagnosed the health problems of the subject, while he sat with closed eyes in a light meditative state. When the healer found the subject's areas of organic dysfunction, she sent information designed to compensate for it. During the approximately fifteen minutes that the healer was concentrating on her task, her EEG waves dipped into the deep Delta region ( between 0 and 3 Hz per second ), with a few sudden eruptions of wave amplitude. This was surprising in itself, because when someone's brain waves descend into the Delta region, he or she is usually in a state of deep sleep. But the healer was fully awake, in a state of intense concentration. Even more surprising was that the test subject exhibited the same Delta-wave pattern--it showed up in his EEG display about two seconds after it appeared in the EEG of the healer. Yet they had no sensory contact with each other."

ADHD Cure

Finding an ADHD cure is on many peoples wish list. When you type in ADHD Cure in a search engine you will find mostly natural and homeopathic remedies that claim to cure
ADHD without medication. I am all for any treatment or therapy that works effectively and does not make the situation worse.

**Accurate Diagnosis of ADHD**

An accurate diagnosis of ADHD begins with a complete history and physical to rule out what it is and what it isn't. There are several medical concerns which can cause symptoms that resemble ADHD. Among them are:

- Hypothyroidism
- Anemia
- Lead Poisoning
- Chronic Illness
- Hearing Impairment
- Visual Impairment
- Substance Abuse
- Medication Side-Effects
- Sleep Impairment or Deprived
- Abuse

It is important to rule these conditions out of the diagnosis, because if it can be determined that one of these is the cause, then you can attempt to treat these conditions, and the ADHD symptoms are very likely to go away. It could be that if one of these conditions are present ADHD may still be present and these may be making those symptoms worse. For example: A sleep deprived child can begin to show "Off the wall" behaviors. That sleep deprivation can be caused by all sorts of things including snoring because of swollen tonsils, or sinusitis that prevents them from getting adequate sleep.

Other causes of ADHD can be hereditary, environmental and dietary. Regardless of the cause there is something that is causing the brain neurons and neurotransmitters to be out of balance, which effects the normal signals that cause the thinking and processing portion of the brain to not work efficiently. Is the goal of all treatments to help restore this imbalance to normal. ADHD is a chronic condition and since we do not know the exact cause, finding a 100% adhd cure has not been done.
Symptoms Must Present in Two or More Settings

Many of the symptoms of ADHD are common not only for young people but for adults as well. Therefore, it is also important to realize that behaviors that are disruptive and worse than normal must be seen in more than one environment before someone can be diagnosed with ADHD. For example ADHD behavior seen only on the playground would not be considered as diagnosed ADHD. See DSM IV Criteria for more information. Some children are being labeled as ADHD when they don't meet these stringent criteria.

Natural ADHD Cures - Herbal Remedies

View any claim that states they have a 100% ADHD cure with their product or book with a degree of skepticism. That being said, with any medical condition there are degrees of severity. Some are mild others are more severe. Some persons may very well respond to a natural or herbal treatment, while others may not, just like some patients will respond better to one medication than another one. So – read, explore all options. Take charge of your situation.

Science of Brain Exercises

Recently, there has been expanding research into how the brain works and what happens when people actually "Use" their brain. This resembles exercise of muscles which will build and strengthen muscles. So it has been found with the brain – when you exercise your brain it actually puts a good stress on the brain. This has been shown similar to muscles being exercised to be good for the brain. It has been shown to actually build and/or
strengthen brain pathways – even create new pathways. There are multiple examples of persons with a brain injury and loss of certain functions who have learned to complete new tasks by forming new pathways.

Doing pioneering research into ADHD treatment through Brain exercises, Dr. Amnon Gimpel has developed a comprehensive approach to treat ADHD in his book: "Brain Exercises to Cure ADHD". Medications alone do not fix the problem. They usually provide effective positive results, but when the medication wears off so does its effect. Recent research reports the finding that the brain's prefrontal lobe which controls executive functions like attention and judgement is often 8–14% smaller in those with ADHD compared to those without ADHD.

In his book Dr. Gimpel identifies many exercises to work on that part of the brain and build more pathways strengthening and building up the frontal lobe. It is these types of behavioral and brain exercises added to medical treatment you are likely to get the best outcomes in your management of ADHD. Perhaps you can learn to manage ADHD and wean off medication using these techniques. Whether with or without medication these exercises are sure to help you as a parent, patient or adult with ADHD.
Praise for ADHD Cure

Brain Exercises to Cure ADHD

"Amnon Gimpel, a psychiatrist and neurologist who has had extensive experience treating patients with ADHD, argues forcefully that parents can do more than just medicate their children. He provides parents with a variety of behavioral techniques, including Brain Exercise Therapy, that are designed to empower both the child and parent, allowing them to control ADHD rather than vice versa. This is a 'must read' book for families coping with ADHD and for health professionals treating this complex and challenging disorder."

"Isaiah Wexler, M.D., Associate Professor of Pediatrics and Head of Pediatric Endocrinology, Hebrew University School of Medicine

Read more about Dr. Amnon Gimpel and his background...Brain Exercises to Cure ADHD, Dr. Amnon Gimpel

Summary - ADHD Cure

There can be no magic fix it all pill or program for every individual who might have ADHD. The best research suggest to use a complete treatment team approach, beginning with personal understanding of as much as possible. Consult your doctor, your advisors, teachers, counselors, and dietician. Try different herbs and adding or eliminating certain foods from your diet. The exercises given in this book will help improve and perhaps offer a cure for some. The theory behind these exercises described here should help any one maintain and perhaps even grow their executive functioning. As we all get older who wouldn't want that
James' Story – A vignette on a child with high-functioning autism.

My youngest son James has been diagnosed with high-functioning autism. At the time I am writing this he is seven, having just had a birthday in July. When he was about four years old, I realized he wasn't progressing as quickly as other children were. When he turned five, I felt he wasn't ready for kindergarten so I held him back from school, thinking he just needed more time to mature. By the time he turned six, I knew he still wasn't ready for school. He seemed to have a learning delay that limited him from progressing mentally at the same rate as other children.

I had heard about an assessment testing program at the University of Utah, where students of the Educational Psychology program did assessments on kids as part of their education, their testing is closely overseen by licensed therapists for accuracy. I decided to have James assessed to see why he had this delayed progression in his learning ability.

After several sessions of testing, James' assessor wanted to have him meet with an autistic specialist because she saw a couple of behavioral traits in him that could signify autism. So I agreed to have this licensed therapist, who specialized in dealing with autistic children, meet with James to see if she felt he was autistic. She came back with the diagnosis that he is indeed autistic. She felt that he is very high functioning and that he is a visual learner, if he sees things he learns much quicker. However, he has a problem processing abstract concepts such as "yesterday, today, and tomorrow" or sequencing "What comes before or after" like with the letters of the alphabet.

I was encouraged by an expert in the field of psychology, who has tremendous experience with cranial electrotherapy stimulation (CES) devices and its science, Charles McCusker, Ph.D. to use one on James for 45 minutes every day or as often as possible for a six weeks. So I did. When I started using the device, I would say that James was at about the level of a three year old mentally though he would be turning seven in about 1½ months.

After about four weeks, I noticed a significant increase in his communication skills. He used to talk a lot but most of it was repeating or mimicking phrases he heard in
cartoons, but now he was actually speaking more to us (our family) about everything. He responded to our questions with appropriate answers and often initiated conversations with us. Before, he might introduce a new phrase very infrequently, maybe once a month. After using the CES device, he started saying many new phrases daily. That was a huge jump in his progression. It was like his brain was processing information better and faster.

One night when I thought he was asleep, I was trying to pull a blanket out from under him to cover him with it, he woke up enough to say "It's OK Mom I don't need it". That, to me, was incredible that he had the cognitive reasoning to first, understand my intentions without me saying anything to him and then to tell me he didn't need the blanket because he wasn't cold. That was something he never would have done before I used the CES device on him. He's done many other similar things since then.

He also had a lot of OCD (Obsessive Compulsive Disorder) like behaviors that he did, like watching which colored tiles he stepped on when he walked through the house or being very particular about closing and locking cabinet doors and the refrigerator door with the baby locks we still had on them from when he was younger. After using the CES, he would run through the house without caring where he stepped and I often have to remind him to close the fridge door. Not a good thing I know, but much more the behavior you would expect from a normal young child. I see it as a sign that there is hope of him developing into a normal functioning adult who can live a normal life.

As I said before, when I began using the CES device on him I felt he was mentally at the level of a three year old, after six weeks of using the CES device, I feel he's more like a four year old. I might add here that I got a little lax about using the device on him every day, (usually, when he was sleeping) and now I've seen him watch which tiles he steps on again so I've started using it on him daily again. I feel confident that the old behaviors he started doing again will stop after a few weeks of using the device and I've decided it's a good idea to keep using it frequently.

If you have a loved one with autism, I highly recommend trying a CES device on them. I'm certain you will see some measure of success with increasing their brain function. By the way, I've also been using this device on myself and have seen my memory and focus improve significantly.

Best wishes in your own success,

James' mom
Case Study/Vignette on "Bob" - May 20, 2004

What a happy New Year it was for "Bob". Our story begins on December 3, 2003 when he and his family came to see me with a rather urgent question, i.e., to help in assessing and addressing his health and behavioral issues. First medical examinations/testing, diagnoses were arranged. The consensus; His general health was in danger of deteriorating if specific behavioral and life-style patterns continued. The key elements of his diagnosis; chronic anxiety, insomnia, low levels of self-control, discipline, and confidence. This pattern had been ongoing for more than 10 years. His own attempts at self-medication involved heavy alcohol and Xanax use (a synergistically toxic combination), and an addiction to nicotine.

Because of "Bob's" high motivation, and a really good attitude, we agreed to undertake what I considered to be an optimal option. We began by having him trace his hand on paper, so that we could have a visual symbol of a five point plan that could result in a successful outcome. Each digit would represent one point: 1.) Self-Love and Acceptance 2.) Education 3.) Exercise 4.) Medication and Stress Control 5.) Nutrition

In the palm of his hand, the letters CES were printed. Then we taped it to the wall. The objective for now was for him to be calm and relaxed for four to five days in a designed environment while focusing on and actually incorporating the five components. "Bob" had already gained a feeling of confidence in his CES unit (Health-Pax) by being well informed and using it daily for 10 days at 100 hz.

Now here comes the fun. As much as possible, I wanted him to be unaware of the time of day. (My previous experiences indicated that persons withdrawing from substances tended to have symptom patterns somehow associated with times of day and circadian rhythms. It was as if they would expect and possibly even program discomforts at particular times. If we can keep them engaged in the plan, relaxed, content and feeling cared for, it can make a big difference.)

This means brown paper and taping all outside light sources, windows, bottom of doors, etc., no radio/tv but lots of funny movies on DVD, music, and telephone conversations - only with those who know about no time tip-offs. (Wait, did we cover the microwave clock with tape?) All of this may sound a little daunting, but it can be done, when the challenge is accepted by a small team (three of us). Can you imagine one preparing meals that must be time neutral, and not forgetting to say "good morning"?

Well, by day three, "Bob" had gone for three days without alcohol or a cigarette (a first for him in about fifteen years). The Xanax plan was follow a progressive deduction in dosage for a specific period (MD advisory). It is now five months of follow-up, and "Bob" and his family assure me that it still is a Happy New Year for all of them.
Summary: The success of our plan can clearly be attributed to; "Bob's" excellent attitude, motivation and his general commitment to following our script; a dedicated assistant who was present and on-call 24 hours, and took care of logistics, meals, etc.; and a firm belief that the CES protocol helped to potentiate and synergize all of the components and elements of the plan.
Advances in Brain Theory Give New Directions to the Use of the Technologies of Brain Mapping in Behavioral Studies*

W.J. Freeman¹ and K. Maurer²

Brain as a Dynamic System

The human brain, for all its complexity and power, is a physical and chemical system that performs its miracles in a physical and chemical world operating by the same dynamic laws. The entire profession of electroencephalography is based on the premise that observations and measurements of the electromagnetic fields of potential at the surface of the scalp and brain, when taken in close conjunction with measurements of behavior, will tell us something about how the brain works and in what ways it can malfunction in disordered states of behavior.

What we mean by "how the brain works" is an explanation in physicochemical terms of how the brain accepts external information from the outside world by way of its sensory receptors and transforms that input first to its own internal information content about the world and then to orderly sequences of muscular contraction. By way of an analogy with a machine, or more generally a homology with a naturally occurring "self-organizing" physicochemical system, we can say that the brain is a dynamic system that accepts input, operates on it to transform it in different ways, and then gives an output. The definition and description of each operation requires that we know enough about the space-time patterns of the input and of the output of each transforming step, so that we can say what must be done to change the former into the latter. For example, one may shine a spot of light onto the retina, measure the discharge patterns of the receptors and of the ganglion cells, and infer that the retina operates on its input (light patterns) to give spatially filtered patterns of action potentials on the optic tract that represent the "sharpened" (contrast-enhanced) stimulus images to the brain.

It is implicit in this description that two kinds of information are to be found in electroencephalographic and magnetoencephalographic measurements of brain activity. One kind consists of the information content that is being operated on by the brain. Brain theory, including the experimental studies on which it is based, tells us that, except for the activity of sensory receptors,

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Topographic Brain Mapping of EEG and Evoked Potentials
Ed. by K. Maurer
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this brain activity does not serve to represent sensory stimuli as they actually impinge on receptors. It serves to embody and convey concepts that the sensory stimuli release, trigger, or enter into. On the motor side the brain activity does not lay action patterns or "commands" onto motor neurons, but instead initiates conceptual trends or trajectories, which are shaped at the level of the spinal cord by proprioceptive feedback into specific movements that instantiate the concepts. Hence the correlates of brain activity are not specific stimuli and responses but are perceptual and concepts that have been established by prior learning (Freeman 1975, 1979, 1981, 1983, 1987; Freeman and Skarda 1985; Skarda and Freeman 1987).

The other kind of information concerns not the content but the operations done on the content. It consists of the unfolding or manifestation of the operations being done on the conceptual information. When a stimulus is delivered to an area of cortex, it is amplified, normalized, integrated over time and space, sharpened, and then forced into a decision tree for the selection of an appropriate concept. These several operations are manifested by a collection of electrical events having specific signatures by which they can be identified and measured. Within the brain, one concept cascades into and through the next, meaning that one vortex of neural activity feeds into and triggers the next, each transition giving rise to its own characteristic signature or electrical "noise" as in the operation of a machine, until the output is brought to completion.

It is the business of brain mapping, among other tasks, to find, read and measure these signatures of brain operations. But in order that we interpret these signs correctly, we must know what the operations are, and for this we must know the "before" and "after" patterns of the conceptual neural information for each operation. In this task we are assisted by the findings of brain theory, which tell us where and how to look for this conceptual information; it is to be found not in the temporal patterns of brain waves, but in their spatial configurations. Brain theory tells us that concepts occur as brief (ca. 100 ms) wave packets, for which a common oscillatory waveform exists among hundreds of millions of neurons in domains of cortex that may extend over tens of square centimeters of cortical tissue. The content of the concept is expressed in the amplitude modulation of the common waveform in its entire spatial extent. The operations of formation, transmission and termination of the concept are expressed in the temporal amplitude modulation and temporal spectrum of the common waveform.

This distinguishing set of characteristics exists by virtue of the nature of the dynamics that gives rise to the neural activity of concepts. In essence the processes of generation are self-organizing. When a large collection of semi-autonomous elements such as cortical neurons is allowed or encouraged to interact extensively, each with very many others in its surround, then a cooperative entity emerges that exists as a macroscopic or large-scale system having much larger spatial and temporal scales than its component have. The cooperative interaction gives rise to the common waveform that is found over the entire extent of the interactive mass of neurons, and that serves as the "carrier wave" of the conceptual information. This information does not appear in the unaveraged activity of single neurons, but only in large averages or sums;
Transcranial direct current stimulation’s effect on novice versus experienced learning

L. M. Bullard, E. S. Browning, V. P. Clark, B. A. Coffman, C. M. Garcia, R. E. Jung, A. J. van der Meer, K. M. Paulson, A. A. Vakhtin, C. L. Wootten, ...

Abstract

Transcranial direct current stimulation (TDCS) is a non-invasive form of brain stimulation applied via weak electrical current passed between electrodes on the scalp. In recent studies, TDCS has been shown to improve learning when applied to the prefrontal cortex (e.g., Kincaid et al. in Neuropsychologia 42:113–117, 2003; Clark et al. in Neuroimage in 2010). The present study 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. Participants completed two 1-h training sessions. During the first 30 min of each training session, either 0.1 mA or 2.0 mA of anodal TDCS was delivered to the participant. The anode was positioned near F8, and the cathode was placed on the upper left arm. Testing trials immediately followed training. Accuracy in classification of images containing and not-containing threat stimuli during the testing sessions indicated: (1) that mastery of threat detection significantly increased with training, (2) that anodal TDCS at 2 mA significantly enhanced learning, and (3) TDCS was significantly more effective in enhancing test performance when applied in novice learners than in experienced learners. The enhanced performance following training with TDCS persisted into the second session when TDCS was delivered early in training.


Anodal transcranial direct current stimulation of the visual cortex for migraine prevention: a proof-of-concept study


Introduction

Prophylaxis is challenging in migraine because of the low efficiency/tolerance ratio of most drugs [1]. Abnormal excitability of the cerebral cortex seems implicated in migraine pathophysiology [2]. Transcranial direct current stimulation (tDCS) can durably modify the activity of a target cortex and thus be a promising treatment [3]. We have shown that the cerebral cortex, namely the visual cortex, is hyperexcitable in migraineurs between attacks and hypothesized that this may be related more to a decreased preactivation level than to hyperexcitability per se [2]. Anodal, rather than cathodal, tDCS might be the stimulation modality of choice in migraine.

Aims

To explore the effect of anodal tDCS on visual cortex reactivity in healthy volunteers (HV) and migraine patients (EM) and its potentials for migraine prevention.

Methods

Amplitude and habituation of pattern-reversal visual evoked potentials (VEP) were measured between the 1st and the 6th block of 100 averagings before and after tDCS (1mA; 15 mins) of the visual cortex on HV (n=11) and on EM (n=12) without aura interictally. To study therapeutic potential, we applied tDCS (15 min) on the visual cortex twice/week for 8 weeks in 7 EM with at least 4 attacks/month and a pre-treatment 2 month baseline.

Results

In HV, tDCS significantly increased the habituation slope of the VEP N1P1 component but had no effect on P1N2. In EM, tDCS tended to increase habituation of both N1P1 and P1N2. At the end of tDCS treatment, there was an average significant reduction in migraine frequency from 9.14 attacks throughout the baseline to 5.57 during tDCS (+36.65%, p<0.05). Mean attack duration changed from 124 to 97 min after tDCS (+43.25%, p<0.05).

Discussion

Anodal tDCS on the visual cortex is thus able to increase habituation of VEP that is reduced in migraineurs interictally. Moreover, 2 weekly sessions of anodal tDCS may have a preventive effect in patients. Hence larger sham-controlled trials with anodal tDCS of the visual cortex are worthwhile in migraine.

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References


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Anodal Transcranial Direct Current Stimulation over the Lower Limb Motor Cortex Increases the Cortical Excitability with Extracephalic Reference Electrodes

Tsuyoshi Takemoto, Tomofumi Yamaguchi, Yohei Otaka, Kunitsugu Kondo, Satoshi Tanaka

Abstract

The aim of the present study was to investigate whether anodal transcranial direct-current stimulation (tDCS) of lower-limb primary motor cortex (M1) could increase cortical excitability when reference electrodes were placed at extracephalic positions. Ten healthy volunteers participated in this study. Anodal electrodes were placed over the left lower-limb M1, whereas reference electrodes were placed on the contralateral forehead (cephalic condition) or contralateral upper arm (extracephalic condition). Motor evoked potentials (MEPs) were recorded as a measure of cortical excitability before and after tDCS (2 mA, 10 minutes). Compared with a sham condition, MEPs significantly increased for both cephalic and extracephalic conditions, and this increase was maintained for approximately 60 minutes after stimulation. No side effects were reported. We conclude that tDCS over lower-limb M1 in conjunction with extracephalic reference electrodes can increase cortical excitability without any side effects.

Conclusion

**tDCS** improves **cognition** in minimally conscious state patients both acute and chronic; traumatic and non traumatic

Future studies:
1. long term tDCS
2. tDCS on M1
3. neurophysiological effects

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Oscillatory brain activity and transcranial direct current stimulation in humans

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The aim of this study was to induce changes of the oscillatory activity in the visual cortex of healthy human subjects by modulation of neuronal excitability using weak transcranial direct current stimulation (tDCS). tDCS is a non-invasive stimulation method which induces prolonged, polarity-dependent increases or reductions in cortical excitability. An increase in high frequency oscillatory activity in the beta and gamma frequency ranges is closely related in time to the N70 peak of the primary visual evoked potential (VEP), which is an early sensory component of visual activation. Therefore this potential can be used to observe tDCS-induced changes related to oscillatory activity. VEPs were recorded using sinusoidal luminance grating in an on-off mode before, immediately after and 0, 20, 30 min after the end of 10 min anodal or cathodal stimulation. Cathodal stimulation significantly decreased while anodal stimulation slightly increased the normalized beta and gamma frequency power. We have shown here that tDCS transiently and reversibly changed the organized cortical activity elicited by visual stimulation. Since gamma activity is also related to a higher level of information processing, tDCS might be a suitable method to affect higher order cognitive processes.

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Key words: Beta activity, Gamma, Grating stimuli, Human, N70, tDCS, Visual evoked potentials

INTRODUCTION

The scalp-recorded visual evoked potential (VEP) reflects the massed activity of a large number of neurons of the human visual cortex. Evidence obtained from dynamic random dot kinetogram dichotic VEPs, from human intracranial and from colour-evoked potential recordings, shows that the N70 component is the earliest VEP peak of cortical origin [1,2]. An increase in high frequency oscillatory activity in the beta and gamma frequency ranges is closely related in time to the N70 peak of the VEP [3,4]. In addition, oscillatory electrophysiological activity of the human brain, especially in the gamma range (30–60 Hz), seems to be associated with different stages of perception and learning [5,6]. The aim of this study is to induce changes of the oscillatory activity in the visual cortex of healthy human subjects by modulation of neuronal excitability using weak transcranial direct current stimulation (tDCS). tDCS is a non-invasive stimulation method which offers the possibility to induce prolonged excitability changes in the motor and visual cortices, as reported by several animal studies [6–8]. These early studies revealed that, depending on the direction of the current in the targeted brain area, cathodal tDCS reduces spontaneous firing rates of cortical cells, most likely by hyperpolarizing the cell body, while anodal stimulation results in a reversed effect. In humans, the method of a non-invasive weak tDCS was recently re-introduced. It has been shown to modulate motor cortex excitability in a polarity-specific way: cathodal tDCS diminished the amplitude of the motor evoked potential (MEP), while anodal stimulation increased it [9]. In the visual modality, cathodal tDCS over the primary visual cortex enhances stationary phosphene thresholds (PTs) whereas anodal stimulation decreases them [10]. Cathodal tDCS also reduces the amplitude of the N70 component of the VEP while anodal stimulation increases it [11]. It has also been observed that tDCS modifies the contrast perception threshold [12]. The effects elicited by tDCS are not restricted to the duration of stimulation itself, but can continue if stimulation intensities and durations are sufficient [9,11,13,14]. However, the durations of the induced after-effects are different for different cortical areas: over the motor cortex the induced after-effects last longer than those induced over the visual cortex.

tDCS can also modify higher-order cognitive processes. Functional studies revealed that in humans, both anodal and cathodal tDCS could hinder use-dependent motor cortical plasticity [15], whereas anodal stimulation of the primary motor cortex improves implicit motor learning [16]. Furthermore, cathodal stimulation of the left VS enhances visuo-motor performance [17].

There is growing evidence that changes in oscillatory activity of the brain play important roles in the formation of perceptions and memory and therefore they are essential for perceptual and behavioural functions [5]. It would be of a great interest if these oscillations could be modified by tDCS. The aim of the present study was therefore to evaluate if tDCS-elevated visual cortical excitability shifts are accompanied by a similar change of oscillatory activity.
Research Shows Music Improves Brain Function

For most people music is an enjoyable, although momentary, form of entertainment. But for those who seriously practiced a musical instrument when they were young, perhaps when they played in a school orchestra or even a rock band, the musical experience can be something more. Recent research shows that a strong correlation exists between musical training for children and certain other mental abilities.

The research was discussed at a session at a recent gathering of acoustics experts in Austin, Texas.

Laurel Trainor, director of the Institute for Music and the Mind at McMaster University in West Hamilton, Ontario, and colleagues
compared preschool children who had taken music lessons with those who did not. Those with some training showed larger brain responses on a number of sound recognition tests given to the children. Her research indicated that musical training appears to modify the brain’s auditory cortex.

Can larger claims be made for the influence on the brain of musical training? Does training change thinking or cognition in general?

Trainor again says yes. Even a year or two of music training leads to enhanced levels of memory and attention when measured by the same type of tests that monitor electrical and magnetic impulses in the brain.

“We therefore hypothesize that musical training (but not necessarily passive listening to music) affects attention and memory, which provides a mechanism whereby musical training might lead to better learning across a number of domains,” Trainor said.

Trainor suggested that the reason for this is that the motor and listening skills needed to play an instrument in concert with other people appears to heavily involve attention, memory and the ability to inhibit actions. Merely listening passively to music to Mozart — or any other composer — does not produce the same changes in attention and memory.

Harvard University researcher Gottfried Schlaug has also studied the cognitive effects of musical training. Schlaug and his colleagues found a correlation between early-childhood training in music and enhanced motor and auditory skills as well as improvements in verbal ability and nonverbal reasoning.
The scientists also discovered that different instruments appear to cause a varying modification within the brain. Changes in the brains of singers occur in slightly different locations than those seen for keyboard or string players.

The correlation between music training and language development is even more striking for dyslexic children.

“[The findings] suggest that a music intervention that strengthens the basic auditory music perception skills of children with dyslexia may also remediate some of their language deficits.” Schlaug said.

Schlaug reports that tone-deaf individuals often have a reduced or absent arcuate fasciculus, a fiber tract connecting the frontal and temporal lobes in the brain. Reduced or damaged arcuate fasciculus has been associated with various acquired language problems like aphasia and also dyslexia in children.

Still more evidence that formal music training strengthens auditory cortex responses came in a study performed by Antoine Shahin, now at Ohio State University in Columbus, Ohio. Shahin believes that musical training gives an individual the acoustic responsiveness of a child some 2 – 3 years older. In talking about the affect of music on the brain, he said the studies do not necessarily show that musical training leads to enhanced IQ or creativity.

Shahin said that when a person listens to sounds over and over, especially for something as harmonic or meaningful as music and speech, the appropriate neurons get reinforced in responding preferentially to those sounds compared to other sounds. This neural behavior was examined in a study that looked at the degree of auditory cortex responsiveness to music and non-familiar sounds as a child ages.
Shahin’s main findings are that the changes triggered by listening to musical sound increases with age and the greatest increase occur between age 10 and 13. This most likely indicates this as being a sensitive period for music and speech acquisition.

Glenn Schellenberg from the University of Toronto directly addressed if musical ability makes a person smarter. Such assessments concerning children are always difficult because of the influence of other factors, such as parental income and education. Nevertheless, he found that passive listening to music seems to help a person perform certain cognitive tests, at least in the short run. Actual music lessons for kids, however, leads to a longer lasting cognitive success.

The effects of musical training on cognition for adults, Schellenberg said, are harder to pin down.

Source: “Music Improves Brain Function,” from livescience.com
A Non-Pharmacology Approach

Cranial Electrotherapy Stimulation

SAFE ■ TESTED ■ PROVEN

Vignette on James – October 9, 2012

James' Story – A vignette on a child with high-functioning autism.

My youngest son James has been diagnosed with high-functioning autism. At the time I am writing this he is seven, having just had a birthday in July. When he was about four years old, I realized he wasn't progressing as quickly as other children were.

When he turned five, I felt he wasn't ready for kindergarten so I held him back from school, thinking he just needed more time to mature. By the time he turned six, I knew he still wasn't ready for school. He seemed to have a learning delay that limited him from progressing mentally at the same rate as other children.

I had heard about an assessment testing program at the University of Utah, where students of the Educational Psychology program did assessments on kids as part of their education, their testing is closely overseen by licensed therapists for accuracy. I decided to have James assessed to see why he had this delayed progression in his learning ability.

After several sessions of testing, James' assessor wanted to have him meet with an autistic specialist because she saw a couple of behavioral traits in him that could signify autism. So I agreed to have this licensed therapist, who specialized in dealing with autistic children, meet with James to see if she felt he was autistic. She came back with the diagnosis that he is indeed autistic.

She felt that he is very high functioning and that he is a visual learner, if he sees things he learns much quicker. However, he has a problem processing abstract concepts such as "yesterday, today, and tomorrow" or sequencing "What comes before or after" like with the letters of the alphabet.

I was encouraged by an expert in the field of psychology, who has tremendous experience with cranial electrotherapy stimulation (CES) devices and its science, Charles McCusker, Ph.D. to use one on James for 45 minutes every day or as often as possible for six weeks. So I did. When I started using the device, I would say that James was at about the level of a three year old mentally though he would be turning seven in about 1½ months.

After about four weeks, I noticed a significant increase in his communication skills. He used to talk a lot but most of it was repeating or mimicking phrases he heard in cartoons, but now he was actually speaking more to us (our family) about everything. He responded to our questions with appropriate answers and often initiated conversations with us. Before, he might introduce a new phrase very infrequently, maybe once a month. After using the CES device, he started saying many new phrases daily. That was a huge jump in his progression. It was like his brain was processing information better and faster.

One night when I thought he was asleep, I was trying to pull a blanket out from under him to cover him with it, he woke up enough to say "It's OK Mom I don't need it". That, to me, was incredible that he had the cognitive reasoning to first, understand my intentions without me saying anything to him and then to tell me he didn't need the blanket because he wasn't cold. That was something he never would have done before I used the CES device on him. He's done many other similar things since then.

He also had a lot of OCD (Obsessive Compulsive Disorder) like behaviors that he did, like watching which colored tiles he stepped on when he walked through the house or being very particular about closing and locking cabinet doors and the refrigerator door with the baby locks we still had on them when he was younger. After using the CES, he would run through the house without caring where he stepped and I often have to remind him to close the fridge door. Not a good thing I know, but much more the behavior you would expect from a normal young child. I see it as a sign that there is hope of him developing into a normal functioning adult who can live a normal life.

As I said before, when I began using the CES device on him I felt he was mentally at the level of a three year old, after six weeks of using the CES device, I feel he's more like a four year old. I might add here that I got a little lax about using the device on him every day, (usually, when he was sleeping) and now I've seen him watch which tiles he steps on again so I've started using it on him daily again. I feel confident that the old behaviors he started doing again will stop after a few weeks of using the device and I've decided it's a good idea to keep using it frequently.

If you have a loved one with autism, I highly recommend trying a CES device on them. I'm certain you will see some measure of success with increasing their brain function. By the way, I've also been using this device on myself and have seen my memory and focus improve significantly.

Best wishes in your own success, from James Mom
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What a happy New Year it was for "Bob". Our story begins on December 3, 2003 when he and his family came to see me with a rather urgent question, i.e., to help in assessing and addressing his health and behavioral issues. First medical examinations/testing, diagnoses were arranged. The consensus; His general health was in danger of deteriorating if specific behavioral and life-style patterns continued. The key elements of his diagnosis; chronic anxiety, insomnia, low levels of self-control, discipline, and confidence. This pattern had been ongoing for more than 10 years. His own attempts at self-medication involved heavy alcohol and Xanax use (a synergistically toxic combination), and an addiction to nicotine.

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Well, by day three, "Bob" had gone for three days without alcohol or a cigarette (a first for him in about fifteen years). The Xanax plan was follow a progressive deduction in dosage for a specific period (MD advisory). It is now five months of follow-up, and "Bob" and his family assure me that it still is a Happy New Year for all of them.

Summary: The success of our plan can clearly be attributed to; "Bob's" excellent attitude, motivation and his general commitment to following our script; a dedicated assistant who was present and on-call 24 hours, and took care of logistics, meals, etc.; and a firm belief that the CES protocol helped to potentiate and synergize all of the components and elements of the plan.
Effect of current strength: Right inferior frontal TDCS, 2.0 vs. 0.6 vs. 0.1 mA

- 0.6 mA TDCS: 17.6% (3.0% SE) increase after training
- No difference in forgetting after 1 hour delay, (F = 0.18, p= .982)

Different recovery mechanisms = different stimulation approaches?

A) Stroke sparing perisylvian cortex
B) Left hemisphere perisylvian recruitment
C) Right hemisphere homolog recruitment
D) Interhemispheric inhibition

Torres et al, 2013
Anodal Transcranial Direct Current Stimulation (tDCS) Decreases the Amplitudes of Long-Latency Stretch Reflexes in Cerebellar Ataxia

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Associate Editor Xiaoxiang Zheng oversaw the review of this article.

Abstract—Recent studies suggest that the neuromodulation of the cerebellum using transcranial direct current stimulation (tDCS) could represent a new therapeutic strategy for the management of cerebellar disorders. Anodal tDCS of the cerebellum increases the excitability of the cerebellar cortex. We tested the effects of anodal tDCS applied over the cerebellum in ataxic patients. We studied (a) stretch reflexes (SR) in upper limb (SLSR: short-latency stretch reflexes; LLR: long-latency stretch reflexes), (b) a coordination functional task in upper limbs based on mechanical counters (MCT: mechanical counter test), and (c) computerized posturography. tDCS did not change the amplitude of LLR, but reduced significantly the amplitudes of LLR and SLSR. tDCS did not improve the MCT scores and did not modify posture. We suggest that anodal tDCS of the cerebellum reduces the amplitudes of LLR by increasing the inhibitory effect exerted by the cerebellar cortex upon cerebellar nuclei. The absence of effect upon upper limb coordination and posture suggests that the cerebello-cerebral networks subserving these functions are less responsive to anodal tDCS of the cerebellum. Anodal tDCS of the cerebellum represents a novel experimental tool to investigate the effects of the cerebellar cortex on the modulation of the amplitudes of LLR.

Keywords—Direct current stimulation, Anodal, Cerebellum, Long-latency stretch reflexes, Excitability, Plasticity.

ABBREVIATIONS

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<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AS20</td>
<td>Ataxia scale on 20 points</td>
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<tr>
<td>dX</td>
<td>Medial-lateral displacement</td>
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<tr>
<td>dY</td>
<td>Anterior–posterior displacement</td>
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<tr>
<td>ECR</td>
<td>Extensor carpi radialis</td>
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<tr>
<td>EMG</td>
<td>Electromyography</td>
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<td>FCR</td>
<td>Flexor carpi radialis</td>
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<td>Long-latency stretch responses</td>
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<td>MCT</td>
<td>Mechanical counter test</td>
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<tr>
<td>PEYO</td>
<td>Eyes open and feet apart</td>
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<tr>
<td>PEYF</td>
<td>Eyes closed and feet apart</td>
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<tr>
<td>PIYO</td>
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<td>SLSR</td>
<td>Short-latency stretch responses</td>
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<td>t-DCS</td>
<td>Transcranial direct current stimulation</td>
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INTRODUCTION

Cerebellar disorders represent a heterogeneous group of diseases. These disabling disorders, also called human cerebellar ataxias, manifest primarily with an impaired control of voluntary movement. Voluntary movement is ataxic, affecting not only single-joint and multi-joint movements in limbs, but also posture. We currently lack efficient drug therapies for most of the cerebellar disorders encountered during daily practice. There is an urgent need to identify novel strategies to antagonize cerebellar motor deficits or to enhance the effects of rehabilitation on this group of disabling disorders.

There is a growing interest in non invasive electrical or magnetic stimulation methods as research techniques to promote neuroplasticity or as therapeutic tools. In particular, transcranial direct current stimulation (tDCS) applied over the cerebellum is a tool currently under investigation to speed up learning of reaching or adaptation during locomotion. In tDCS, a steady current of small intensity (usually 0.5, 1 or 2 mAmp) passes between two large electrodes affixed on the scalp. Continuous or intermittent anodal tDCS induces a polarity-dependent site-specific modulation of brain activity. Anodal tDCS induces a
Trans-cranial Direct Current Stimulation Intensity and Duration Effects on Tinnitus Suppression

**Background.** Perception of sound in the absence of an external auditory source is called tinnitus, which may negatively affect quality of life. Anodal transcranial direct current stimulation (tDCS) of the left temporoparietal area LTA was explored for tinnitus relief. **Objective.** This pilot study examined tDCS dose (current intensity and duration and response effects for tinnitus suppression). **Methods.** Twenty-five participants with chronic tinnitus and a mean age of 54 years took part. Anodal tDCS of LTA was carried out. Current intensity 1 mA and 2 mA and duration 10 minutes, 15 minutes, and 20 minutes were varied and their impact on tinnitus measured. **Results.** tDCS was well tolerated. Fifty-six percent of participants experienced transient suppression of tinnitus, and 44% of participants experienced long-term improvement of symptoms overnight—less annoyance, more relaxed, and better sleep. There was an interaction between duration and intensity of the stimulus on the change in rated loudness of tinnitus. F(2, 48) = 4.355, p = .018, and clinical global improvement score, F(2, 48) = 3.193, p = .050, after stimulation. **Conclusions.** Current intensity of 2 mA for 20 minutes was the more effective stimulus parameter for anodal tDCS of LTA. tDCS can be a potential clinical tool for reduction of tinnitus, although longer term trials are needed.

Vincent Walsh TMS > tDCS & Migraine

**Toward the end of the video (The Daily Telegraph 2008) Professor Vincent Walsh, (now of University of California Davis) discusses tDCS and its potential for therapeutic use. Especially of interest is the information on migraine headaches:**

> So, some migraines are caused by having too much activity in the visual brain area, and some are by having too little activity. And we hope that this can balance out, reverse that relative inactivity in the brain.

Could this imply that one person’s migraine could be mitigated with Cathodal (-) tDCS, while another might benefit from Anodal (+) application of tDCS? And conversely, does it imply that improper stimulation would lead to MORE migraines?

If I suffered from migraines and wanted to test tDCS, here’s where I’d start:

- Check the [Fisher Wallace](https://www.fisherwallace.com) and [Find A Doctor search](https://www.findadoctorsearch.com) page for an electrotherapist in your area.
- If they will treat you for migraine, try a few sessions. If it works, and your doctor will authorize a purchase, you can buy your own unit (for $700). A [Fisher Wallace](https://www.fisherwallace.com) device may qualify for insurance coverage.
- Alternately, I would monitor the [ClinicalTrials.gov](https://clinicaltrials.gov) site and keep an eye out for new studies testing tDCS for migraine. And lastly, I would contact manufacturers of other tDCS devices and ask if they knew of any electrotherapy practitioners in your area working with migraine. Here’s my short list of manufacturers to contact:
Induction of visual dream reports after trans-cranial direct current stimulation (tDCs) during Stage 2 sleep – JAKOBSON – 2012 – Journal of Sleep Research

This is encouraging because a previous study showed minimal effect on dreaming using tDCS. In both experiments a significantly greater number of imagery reports were found on awakening after tDCs (cathodal–frontal, anodal–parietal), compared to the blank control conditions. However, in Experiment 2 the frequency of imagery reports from the tDCs (cathodal–frontal, anodal–parietal) was not significantly different from the other two tDC conditions, suggesting a non-specific effect of tDCs. Overall, it was concluded that tDCs (cathodal–frontal, anodal–parietal) increased the frequency of dream reports with visual imagery, possibly via a general arousing effect and/or recreating specific cortical neural activity involved in dreaming.
Abstract

The sleeping brain exhibits characteristic slow-wave activity which decays over the course of the night. This decay is thought to result from homeostatic synaptic downscaling. Transcranial electrical stimulation can entrain slow-wave oscillations (SWO) in the human electroencephalogram (EEG). A computational model of the underlying mechanism predicts that firing rates are predominantly increased during stimulation. Assuming that synaptic homeostasis is driven by average firing rates, we expected an acceleration of synaptic downscaling during stimulation, which is compensated by a reduced drive after stimulation. We show that 25 minutes of transcranial electrical stimulation, as predicted, reduced the decay of SWO in the remainder of the night. Anatomically accurate simulations of the field intensities on human cortex precisely matched the effect size in different EEG electrodes. Together these results suggest a mechanistic link between electrical stimulation and accelerated synaptic homeostasis in human sleep.

Author Summary

Sleep pressure is reflected in the power of slow-wave activity: it is high after extended wakefulness and gradually decays in the course of the night. Transcranial stimulation with slow-oscillating currents can entrain electro-encephalographic slow-wave oscillations (SWO) and transiently increase their power. Motivated by the results from a multi-scale computational model, we tested in humans whether 25 minutes of transcranial stimulation attenuates the decay of SWO in the remainder of the night. A Finite-Element Model (FEM) is used to estimate the current flow in the brain and a network model of spiking neurons determines the resultant effect on SWO. This multi-scale model predicted increased neuronal firing rates leading to accelerated synaptic downscaling. As a consequence, the decay of SWO power and spatial coherence after stimulation is reduced. In addition to reduced decay rate, the model was also able to successfully predict, in the human experiments, the spatial distribution of the effect across EEG electrodes. These combined experimental and modeling results suggest a mechanism by which electrical stimulation can accelerate synaptic homeostasis and thereby influence a putative process of sleep regulation. The ability to accelerate the homeostatic function of sleep may have important practical implications.

Figures

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Introduction

Human sleep is characterized by distinct sleep stages which can be readily identified in the electroencephalogram (EEG). Of particular interest is the activity in the 0.5–4 Hz frequency band known as slow-wave activity (SWA). The power of SWA increases following extended waking and decreases in power and spatial coherence throughout the night [1, 2]. SWA activity is thought to reflect a homeostatic mechanism that regulates sleep [3]. These changes in power have been hypothesized to result from potentiation and downscaling of synaptic connections during wakefulness and sleep respectively [4–9].

Homeostatic plasticity refers to a physiological feedback mechanism that regulates average firing rates by altering synaptic strength: high firing rates lead to synaptic depression and low firing rates to potentiation [10]. A link between homeostatic plasticity and sleep homeostasis is supported by the parallels between firing rates and SWA: namely, extended waking results in increased cortical firing rates at the beginning of sleep, and firing rate decays again during sleep [11].

Here we consider slow-wave oscillations (SWO, 0.5–1 Hz) in the human EEG as a marker for sleep homeostasis and its modulation by transcranial electrical stimulation. We found that a relatively short 25 minutes of stimulation in humans during slow-wave sleep at the beginning of the night had a lasting effect on homeostatic decay of SWO in the hours following stimulation.

The effects of transcranial electrical stimulation on brain activity have been the subject of intense investigation in the last decade [12, 13]. A number of studies show specific enhancement in human cognitive performance including memory, language, computational, and executive function [14–17]. The mechanisms leading to the observed cognitive effects of weak electrical stimulation in human behavioral studies remain fundamentally unaddressed. The current mechanistic explanation is limited to the notion of neuronal excitability where function is “increased” or “decreased” by virtue of neuronal polarization with anodal or cathodal stimulation respectively. However, the basic physics of current flow calls this simple notion into question as cortical folding leads to varying polarity across cortex making the origins of polarity specific effects unclear [18]. Furthermore, while acute effects of uniform week electric fields are well characterized, including modulation of firing rates [19], it is less clear how these acute effects translate into specific long term effects.

We hypothesized that stimulation during slow-wave sleep alters neuronal firing rates, which would modulate homeostatic synaptic downscaling and thus alter the homeostatic decay of SWO. A multi-scale computational model makes this hypothesis explicit by linking the macroscopic domains of current flow in the entire head with the microscopic cellular effects of polarization. The model shows that network dynamics of SWA can rectify bi-directional
polarization leading to an unidirectional increase of firing rates and synaptic downscaling. A number of predicted effects of stimulation on SWO are subsequently confirmed by the present human EEG sleep data. Specifically, the data confirmed the prediction of diminished SWO decay in the hours after stimulation, and the multi-scale model accurately predicted the effect sizes across multiple scalp electrodes.

The ability to accelerate sleep homeostasis may have important practical implications given that SWA is widely considered to be a marker of the restorative power of sleep.

**Results**

*SWO power and spatial coherence decay with time during sleep*

In a study on memory consolidation during sleep [14] Marshall et al. stimulated participants during the first period of slow-wave sleep with slow-oscillating unipolar stimulation (0.26 mA switched on and off at 0.75 Hz). Positive (anodal) electrodes were placed bilaterally over lateral prefrontal cortex and negative (cathodal) electrodes over left and right mastoids. EEG was recorded simultaneously from 11 electrodes (Figures 1.A.1, 1.A.2). To characterize the long term effects of stimulation on slow-wave activity, we computed here for each participant the power-spectrum over the course of the night. Slow-wave activity (0.5 Hz–4 Hz) is modulated in time as participants cycle through non-REM and REM sleep stages (Figure 1.B.1, average over 10 participants). Note that the EEG data were aligned based on sleep stages (see Materials and Methods), and sleep-stage cycle-durations are fairly reproducible across subjects [14],[20]. We estimated decay rates of power and coherence as a linear fit on a logarithmic scale (dB), which corresponds to an exponential decay in time (example traces in Figure S1.A–B)[21]–[23]. In the present data the homeostatic decay of power in the band of slow-wave oscillations (0.5 Hz–1 Hz) amounted to $-1.22 \pm 0.18$ dB/hour (mean $\pm$ sem, p-value = 0.0001, N = 10, Student's t-test, Figure 1.B.3, analysis window of 4.5 h marked in black, see Materials and Methods). In addition to changes in power, the computational model, which will be presented in the following sections, predicted that the spatial coherence of SWO should also decay. The coherence-spectrum between electrode pairs was computed and averaged across all pairs (Figure 1.C.1, average over 10 participants). In the band of SWO, coherence decays at a rate of $-0.70 \pm 0.12$ dB/hour (mean $\pm$ sem, p-value = 0.001, N = 10, Student's t-test, Figure 1.C.3). The present measure of spatial coherence is normalized by power. Thus, its decay does not simply capture a decrease in power but reflects instead a break-up of large scale coherent oscillations over distant cortical areas consistent with recent recordings in humans[2].
Figure 1. Transcranial electrical stimulation affects power and spatial coherence of human EEG during sleep.

EEG is recorded from 11 electrode locations, stimulation electrodes are placed bilaterally on the scalp. **A.1:** In the sham condition stimulation electrodes were placed but no current was applied. **A.2:** In the stimulation condition slow-oscillating (0.75 Hz) current is applied for 25 minutes at the beginning of the night. **B.1–B.2:** Spectrograms of power in sham and stimulation conditions during the night in the human EEG data (average across subjects, Pz electrode). **C.1–C.2:** Spectrograms of spatial coherence between Pz and other EEG electrodes. **B.3:** Decay rate of power in the SWO band during the analysis period (4.5 hours after the stimulation). Colors indicate subject. **C.3:** Decay rate for spatial coherence in the SWO band in the analysis period. Stimulation and sham condition differ significantly in decay rate for both power and coherence (paired shuffled statistics, N = 10 subjects).
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**Homeostatic decay of SWO is altered by slow-oscillating transcranial electrical stimulation**

Our hypothesis on homeostatic plasticity predicted that the decay of SWO should be altered by the transcranial slow-oscillating stimulation administered to participants for 25 minutes (spectrograms in Figures 1.B.2, 1.C.2). Specifically, we expected a reduced rate of decay in both power and spatial coherence in the hours following stimulation. This prediction was confirmed by the present data: the post-stimulation decay rate for power averaged over all electrodes is reduced to $\sim0.69\pm0.18$ dB/hour (N = 10, paired shuffled statistics, p = 0.016, Figure 1.B.3) and similarly, the rate of spatial coherence is reduced to $\sim0.15\pm0.12$ dB/hour (N = 10, p = 0.009, Figure 1.C.3). Significant differences in decay rate are found also when analyzing individual electrodes in isolation (p-values corrected for false discovery rate are between 0.013 and 0.035 for all electrodes except F7 with p = 0.132) and the same is true for coherence (p-values between 0.013 and 0.031 except T3 with p = 0.063). The wider band of SWA (0.5–4 Hz)
yielded essentially the same results (p<0.05). Changes in sleep structure are hard to assess from the average spectrogram in Figures 1.B-0.C. Previous analysis already dismissed possible changes in terms of time spent in different sleep stages during the 60 minutes after the stimulation or the whole night, nor were there differences in the number of sleep cycles [14].

In summary, as predicted, the decay of SWA, which is widely considered to be a marker of sleep homeostasis, is reduced in the hours following electrical stimulation. In the following section we make quantitative predictions of this phenomenon by detailing our hypothesis in the form of a multi-scale computational model. We include a finite-element model of the current flow in the brain as well as a network model for slow wave oscillations.

*Transcranial electrical stimulation in humans polarizes the cortical surface with mixed polarity*

To determine the expected effects of stimulation for this specific human experiment we first simulated the current flow in an anatomically accurate model of the head (Figure 2.A.1, see Materials and Methods). Electrodes were placed as in the human experiments and currents were monophasic (ON/OFF). As a result of the typical folding of human cortex, different cortical regions experience electric fields of varying magnitudes and, more importantly, of opposing polarities (blue and red in Figure 2.A.2). Thus, neurons in adjacent cortical areas will experience opposing membrane polarizations (Figure 2.A.3). This finding is not unique to the specific electrode montage [18].

![Figure 2. Multi-scale model of transcranial electrical stimulation.](image)
(inward) and hyperpolarizing (outward) radial fields. **B.1:** The network model consists of excitatory and inhibitory neurons arranged in a 2D-lattice with long- and short-range synaptic connections respectively. Field magnitude and polarity of the stimulation applied follow the FEM computations and were applied to the network depending on the location within the lattice (applied polarity indicated with red/blue shading). **B.2:** Spiking activity of neurons in the network reproduces the typical UP and DOWN states of SWO. The LFP (black line) is determined as the average of the post-synaptic currents (gray line, LFP low-pass filtered, cut-off frequency 2.5 Hz). **B.3:** Example of network activity (LFP in white). Oscillation is in the range of human SWO (0.5–1 Hz). Spectrogram indicates power of this signal. Red curve indicates slow-oscillating ON/OFF stimulation (0.75 Hz) which is applied to the excitatory neurons in the network.

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**Slow-oscillating stimulation increases firing rate during SWO despite mixed polarity**

To examine the effect of differing stimulation polarities on SWO we developed a simple network model of UP/DOWN state transitions. Single-compartment excitatory and inhibitory spiking neurons were recursively connected and arranged on a 2D lattice (900 neurons, Figure 2.B.1). The model reproduces slow-wave oscillations by virtue of an activity-dependent slow recovery variable in a fashion comparable to previous models of SWO [9], [24]–[26] (Figure 2.B.2). The recovery variable acts to decrease neuronal excitability after periods of high activity (UP-state) and recovers after periods of quiescence (DOWN-state). The parameters of the model were chosen to reproduce key features of SWO in humans, such as oscillation frequency and coherence time, and the firing rate of single neurons was adjusted to match animal *in vitro* data (Figure 2.B.3, see Materials and Methods). Note that network parameters were chosen here to reproduce the irregular slow-wave pattern typical of human EEG data (i.e. short coherence times, see Materials and Methods). These contrast the very regular oscillations often measured in *in-vitro* preparations [26], [27] which can be readily reproduced by the present model by increasing the strength of synaptic connections (see Materials and Methods). The effects of weak-field stimulation were implemented as a weak current injection to pyramidal neurons. The specific model of field-to-neuron coupling was validated at multiple frequencies in terms of firing rates, spike timing and entrainment using rat hippocampal slice recordings [19]. The same modeling approach was also used to model acute entrainment of slow waves oscillations in cortical ferret slices [28].

Different areas of the network were subjected to depolarizing or hyperpolarizing fields corresponding to the mixed polarities of the macroscopic field distributions (Figure 2.B.1). We find that when the network is subjected to constant current stimulation, average firing rates during slow-wave oscillations were increased or decreased depending on the predominant stimulation polarity (Figure 3.A.1). However, when stimulation was turned on and off at the same rate as the slow-oscillations (0.75 Hz), firing rate was only increased (Figure 3.A.2). This remarkable rectification of field-effects on firing rate is the result of the entrainment of the slow-wave oscillation to the applied oscillating field as will be explained below.
Figure 3. Entrainment of network oscillations to weak electric field stimulation and effects on homeostatic synaptic downscaling.

A.1: Change in average firing rate by constant current stimulation (DC) as a function of the stimulation intensity and the fraction of neurons polarized in either direction (depolarized and hyper-polarized). Firing rate increases or decreases depending on predominant polarity of field stimulation. A.2: Change in average firing rate during slow ON/OFF stimulation (0.75 Hz) as in A.1. Note the rectification of the effect of fields on firing rate, which now only increases for inward stimulation but does not decrease for outward currents. A.3: Entrainment of the network with 0.31 V/m monophasic ON/OFF stimulation for purely cathodal (blue) or purely anodal (red) field. Note that the ON period of stimulation aligns with the DOWN state for cathodal and with the UP state for anodal stimulation. A.4: Phase of network oscillations relative to the oscillating stimulus as a function of the same parameters as in A.1. B.1: Applying a firing-rate dependent synaptic update rule leads to a gradual decrease of average synaptic strength given the relatively high firing rate of the UP state. Electrical stimulation (red curve) accelerates this effect relative to sham (green curve). B.2–B.3: The immediate effect of decreased synaptic connections is a decrease in power and spatial coherence of network oscillations. In the stimulation condition, both power and spatial coherence after the stimulation are lower than in sham condition and they decay at a slower rate after stimulation. The results represent $N = 10$ simulations with randomly chosen synaptic connections, bars indicate standard error of the mean.

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Entrainment of SWO to oscillating stimulation explains rectification of firing rate effect

The network model suggests that weak oscillating stimulation can entrain SWO even for very low amplitude fields (Figure S2.A) and that entrainment results from a modulation of the duration of the UP and DOWN state (Figures S2.B.1-S2.B.2). Entrainment, as previously reported [14] is confirmed here with the present analysis of EEG data (Figure S2.C.1-C.2, Pz electrode, Rayleigh test, 5 trials per 13 subjects considered, p = 0.017). Entrainment of UP/DOWN-state transitions for weak applied fields have also been reported in ferret slices [28] and spiking activity was also entrained in in vivo recordings in rat [29]. Neither study reported any long term effects of fields on SWO.

For monophasic stimulation, as in the present study, entrainment occurs regardless of polarity, but does so with opposing phase for opposing polarities (Figure 3.A.3). In the case of depolarizing stimulation (anodal with currents flowing into cortex), the ON period of stimulation aligns with the UP-state, while in the case of hyperpolarizing stimulation (cathodal with currents flowing out of cortex), the ON period aligns with the DOWN-state (Figure 3.A.4). The depolarizing field during the UP-state can increase the firing rate of this active state. However, hyperpolarizing fields during the DOWN-state can not reduce firing rate as the network is already quiescent.

Thus, while DC stimulation may lead to mixed effects on firing rate across space, applying slow-oscillating ON/OFF stimulation during SWO may rectify the effects of fields leading to an unidirectional increase in firing rate.

Electrical stimulation affects homeostatic downscaling in the network model

In vivo animal experiments suggest that synapses undergo downscaling during sleep [5] and that this coincides with a reduction in firing rates [11]. This is consistent with homeostatic synaptic plasticity, which adapts synaptic strength so as to stabilize firing rate to a set level[30]. We implemented here a slow, activity-dependent negative feedback on excitatory synaptic strength. Given the relatively high firing rate of the UP-state, this leads to widespread synaptic downscaling (green curve in Figure 3.B.1), and in turn, to a decrease in the power of slow-wave oscillations in the course of time (Figure 3.B.2). Spatial coherence of slow-wave oscillations also decreased with time (Figure 3.B.3). Both results are consistent in direction and magnitude with the present human EEG data (Figures 1.B.1 and 1.C.1).

We argued above that slow-oscillating stimulation leads to an acute increase of firing rate, even at the small field intensities expected on human cortex of less than 0.5 V/m. In the network model this increased firing rate caused faster synaptic downscaling (Figure 3.B.1, using a field magnitude of 0.31 V/m). With this accelerated downscaling during stimulation, at the end of stimulation, firing rates are reduced as compared to the sham condition. Thus, with a diminished drive for downscaling, in the hours after stimulation the rate of SWO decay was correspondingly reduced – in power as well as spatial coherence (decays in Figures 3.B.2–3.B.3 and results in Figures 4.A.1–4.A.2).
Figure 4. Multi-scale model predicted the after-effects of the stimulation and their variation across electrode locations.

A.1–A.2: Decay rate after the stimulation for sham and stimulation condition in the computational model for power and spatial coherence. Compare this to the measurements in the human EEG data in Figure 1.B.3–C.3. B: Spatial distribution of decay rates across the 11 scalp electrodes averaged across subjects. 1: for EEG power in sham condition, 2: for EEG power in stimulation condition. 3: Approximate fit of network model parameters to match human sham data for each electrode location. 4: Resulting decay rates for the location-matched network models with stimulation intensity and polarity determined from the FEM model in a 1 cm vicinity of each electrode location. C: Change in decay rate of power for stimulation condition. Each point represents one electrode with EEG data on vertical and multi-scale model on horizontal axis. EEG data significantly correlates with model prediction.
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In the human experiment acceleration during stimulation could not be measured directly because entrainment and stimulation artifact distort the endogenous EEG signal. Instead, we measured the slope of decay after stimulation (Figures 1.B.3 and 1.C.3). These measures matched the model predictions shown in Figures 4.A.1–4.A.2: the difference in the decay for power between the stimulation and sham conditions in the EEG data is $0.58 \pm 0.23$ dB/hour and $0.62 \pm 0.31$ dB/hour in the computational model; for spatial coherence the difference in decay rate is $0.54 \pm 0.20$ dB/hour and $1.43 \pm 0.78$ dB/hour respectively.

**Accurate spatial prediction of effect size**

To further test the link between stimulation and downscaling, we analyzed the effect size for each of the 11 recording sites. For the human experiment the rate of decay in power was determined for each electrode and averaged across subjects for the sham and stimulation conditions (Figure 4.B.1–4.B.2). We ran the model without stimulation using random synaptic weights and selected for each location a set of weights that approximately matched spatially the EEG sham condition in terms of their decay rate (Figure 4.B.3). We then applied stimulation to the model of each “location” using the intensity distribution of fields found in the FEM model in the vicinity of each electrode. We used the field intensity orthogonal to the cortical surface since cell polarization is approximately proportional to the field intensity in the main axis of pyramidal cells [31]. The average value of the electric field chosen was 0.93 V/m (in this case the stimulation is depolarizing or hyperpolarizing for different locations of the network; see Materials and Methods). This resulted in a decay rate for each “location” as shown in Figure 4.B.4. The spatial distribution is remarkably similar to the one observed in the human EEG.
Indeed, the effect size of stimulation versus sham across electrodes was significantly correlated with the predicted values (N = 11 electrodes, $r^2 = 0.47$, $p = 0.02$, Figure 4.C).

In summary, the model not only explained the systematic reduction in decay rate of SWO power after stimulation despite mixed polarity stimulation, but it also predicted the effect size in each location by considering the specific mix of polarities near each electrode.

**Discussion**

Slow-wave activity has long been associated with the restorative function of sleep [32] and recovery from wakefulness [5], [21]. EEG slow-wave oscillations reflect periodic transitions between UP and DOWN states broadly distributed over the cortex [33] and are thought to be involved in plastic mechanisms [34]. The power of SWA has been linked to learning; for instance, practice on a visuomotor task preceding sleep increases SWA and its strength correlates with task performance following sleep [6], [8]. SWA is also hypothesized to play a crucial role in memory consolidation by virtue of its ability to group the activity of various brain rhythms [35] (e.g. hippocampal ripples; [36], [37] and thalamo-cortical spindles [38].)

A predominant feature of SWA is its decay in the course of the night. Many investigators attribute this decay to homeostatic downscaling of synaptic strength [5], [6], [9]. In their view, synaptic connections that became stronger during wakefulness are reduced in magnitude during sleep. Consistent with homeostatic synaptic plasticity, this decrease coincides with a reduction in firing rates [11]. Homeostatic plasticity represents a negative feedback that adapts synaptic strength resulting in a steady level of neuronal activity [10]. Synaptic downscaling during sleep has been postulated to serve a number of important functions, such as maintaining computational efficiency of the brain by increasing the signal-to-noise ratio of synaptically decoded information [35]; allowing maximum storage efficiency while preventing hyperactivity [39]; and maintaining synaptic normalization [40]. The physiological substrate for the scaling of synaptic connections could be explained by considering that the levels of neuromodulators strongly differ from waking to NREM sleep, for example the concentrations of acetylcholine [41], [42] and norepinephrine [43] are significantly altered. Alternatively, spike-timing dependent plasticity (STDP) during neuronal bursts in slow-wave sleep may favor synaptic depression [44]. Downscaling has also been proposed to result from bursts of activity leading to long-term depression during NREM sleep [45]. Recent studies also point to a possible role of glial cells in determining synaptic scaling. [46].

We previously showed that slow-oscillating transcranial electrical stimulation can modify endogenous slow oscillatory activity on a short term basis [14]. The question for the present work was whether cortical homeostatic mechanisms are influenced by slowly oscillating transcranial stimulation.

Anatomically accurate models of current-flow in transcranial stimulation estimate that the electric fields induced at the cortical level for a typical 2 mA stimulation are at most 1 V/m [18]. This may polarize a cell by no more than a fraction of a millivolt [31], [47]. While these intensities seem very small, there are a number of in vitro and in vivo experiments explaining the basic mechanisms by which such low-amplitude electric fields may nevertheless acutely alter neuronal activity, both at the single cell [48] and at the network level [19], [49]–[51]. In
particular, it has already been shown, both experimentally and using computational models[19], [28], that the effects resulting from the modest membrane polarization of isolated neurons are significantly amplified on the network level due to the dynamic nature of network activity. This can result in altered firing rates and altered oscillatory rhythms. For instance, the modulation of gamma activity with theta oscillations in the hippocampus is conceivably entirely due to the small fields generated endogenously in the theta band [19]. Similarly, slow-wave activity can be entrained by very weak endogenous fields in vitro [28] or weak applied currents in vivo [29]. Most importantly, however, there are a multitude of studies in human showing long term plastic effects (e.g. [13], [52]–[56], just to name a few). These are often simply described as lasting changes in neuronal excitability [57]. However, the mechanisms by which weak stimulation could modulate/induce plasticity are less well understood. In humans, both enhancing and suppressing effects have been found with either polarity of stimulation. Some studies argue that depolarizing currents enhance glutamatergic or NMDA dependent Hebbian-type plasticity [58], [59], while other studies have invoked homeostatic plasticity [60]. Lasting effects on synaptic efficacy have only recently been found in vitro [61], [62]. These studies demonstrate that very specific conditions on network activity are required in addition to weak-field stimulation in order to observe lasting changes in synaptic efficacy [63].

In the present study we have aimed to provide a detailed explanation of how weak fields, which are capable of modulating network firing rates [19], may alter ongoing homeostatic plasticity, and how this translates into observable macroscopic effects on EEG slow-wave oscillations. Crucial for our predictions was a network model of slow-wave oscillations that is based on UP/DOWN state transitions. We showed that SWO entrain to weak-field slow-oscillatory stimulation consistent with experiments in vitro [28] and in vivo [29]. We also confirmed entrainment here again on the human EEG data (Figure S2.C.1). The model exhibited entrainment for depolarizing, hyperpolarizing and mixed polarity stimulation (Figures 3.A.3–3.A.4). Importantly, we demonstrate how this entrainment rectifies the effects of fields of mixed polarity to result only in increased firing rates (Figure 3.A.2). When combined with homeostatic plasticity, the model reproduced slow-wave decay in power similarly to previous more complex computational models [9] (Figure 3.B.2). Interestingly, the present model also reproduced the recently observed breakup of global coherent oscillations [2] reflected here in declining spatial slow-wave coherence (Figure 3.B.3) – a finding that we confirmed also in the human EEG data (Figure 1.C.1). We used a simple negative feedback on firing activity to implement homeostatic plasticity. Specifically, the model predicted that an acute increase in the firing rate results in a faster homeostatic downsizing of synapses. Thus, we predicted a reduced decay of slow-wave decay (in power and coherence) in the hours after stimulation (Figure 3.B.2–B.3). Human SWO subsequent to stimulation were indeed modulated as predicted (Figure 1.B.3–C.3). The results are further confirmed by the precise agreement of model predictions with the varying effect size observed across electrodes (Figure 4.B–4.C).

The choice of a target firing rate was made to reproduce the experimentally observed decrease in firing rate during slow-wave sleep as reported in in-vivo experiments [11]. Previous models of SWO implemented a reduction of synaptic strength explicitly [9] or implicitly using STDP [64]. More complex models of plasticity, such as the BCM model [65] are expected to lead to similar predictions.
An alternative interpretation of the observed reduction in decay rate after stimulation may be an alteration of sleep stages, e.g. the first slow waves stage was disrupted. However, it is not clear how this hypothesis would lead to different effects at different electrode locations. It is also possible that fields have a direct effect on synaptic strength, but current literature suggests that very specific conditions need to be satisfied for plastic effects to be observed. While we made no direct observation of firing rates nor synaptic strengths, the agreement between the present multiscale model and the human EEG data does support the hypothesis that field-induced cell polarization results in an increase of firing rate and that this accelerates synaptic downscaling during oscillatory transcranial stimulation.

**Materials and Methods**

**Human EEG data after stimulation in sleep**

EEG data was recorded on human subjects from the beginning of the night sleep until wake the next morning in the study described by [14]. Briefly, transcranial stimulation with slow-oscillating currents (ON/OFF at 0.75 Hz with trapezoid waveform) was performed after subjects had attained stable stage 2 or deeper non-rapid eye movement sleep (according to [66]). Stimulation was repeated altogether 5 times for 5 minutes followed by 1 minute intervals without stimulation (total of 25 minutes stimulation plus four one-minute intervals). Anodal stimulating electrodes were placed bilaterally at F3 and F4 and cathodal electrodes on mastoids M1 and M2 (10/20 system, Figure 1.A.1). Current intensity on each hemisphere oscillated between 0.26 mA (on) and 0.0 mA (off) and was below perception. To assure that stimulation intensities were below perception thresholds we stimulated subjects for 10 seconds (active and sham) when subjects were in bed but lights were still on. Immediately after, subjects were asked whether they had felt anything on their head. The subjects responses did not differ between the active stimulation or sham stimulation, indicating that the stimulation was indeed below perception. Note that the stimulation used in the study are significantly lower than the maximum used during transcranial stimulation (2 mA, [13], [55]) and so well below the current amplitudes considered safe for human studies [67], [68]. To test further for possible side effects, heart rate was monitored during sleep, i.e. during stimulation and thereafter. No obvious changes in heart rate were observed during the stimulation. The experimental protocol was approved by the ethics committee of the University of Lübeck.

For the present analysis EEG data with complete sleep scores included 10 subjects for the sham conditions and 13 subjects with active stimulation. Paired tests were thus limited to 10 subjects. Acute entrainment of EEG to the oscillatory stimulation on this data has been previously reported [14]. However, this previous analysis did not consider the phase of entrainment nor slow-wave spatial coherence, and more importantly, it did not analyze long term decay of SWO in the hours following stimulation.

**Power and spatial coherence changes in the human EEG data.**

Slow-wave power varies significantly with different sleep stages. In order to compare slow-wave power from different recording sessions it is therefore important to align sleep stages. The EEG data were aligned to the first uninterrupted 1 minute period in sleep stage 2. With this, the SWO
power (0.5–1 Hz) in the minute preceding the stimulation period did not differ between sham and stimulation conditions (N = 10 and N = 13 for sham and stimulation conditions respectively, \( p = 0.63 \), two-sample Kolmogorov-Smirnov test). SWO power was measured for each electrode in periods of 40 seconds by averaging power in the corresponding frequency bins after Fourier transform. Spatial coherence was determined from the normalized cross-correlation by Fourier transforming, squaring, and averaging across SWO frequency bins. Values are computed for each electrode by averaging coherence of all pairs involving the electrode. These power and coherence measures are obtained for all 40 seconds intervals. Their decay rate during the night was measured as the slope of these curves using a linear robust fit. The fit considered a 4.5 hour period starting at the end of the stimulation until 30 min before the end of the shortest signal (to avoid contamination from awakening). Non-parametric statistics were obtained by randomizing the labels (sham vs stimulation) and computing mean decay rates with random labels. \( p \)-values were computed using these shuffle statistic. Correction for multiple comparisons across electrodes controlled the false-discovery rate (FDR).

**Computational model**

**Single-cell model.**

We restrict our model to a single compartment neuron. This simplification omits the effects of fields on the dendritic arbors [47] yet is sufficient to describe effects on spiking activity [19],[48]. We used Izhikevich's model [69], [70] with a set of parameters that reproduces the physiological spiking behaviors of cortical neurons. The equations describing the neuronal dynamics and the details on the network model can be found in [69] and in our previous study[19].

**Network model.**

The network model consists of \( N_e = 720 \) excitatory neurons and \( N_i = 180 \) inhibitory neurons arranged at random on a 2D lattice. When a spike is elicited by neuron \( m \) the synaptic input current to neuron \( n \) is given by the synaptic currents of AMPA and NMDA channels (for excitatory pre-synaptic neurons) and \( \text{GABA}_A, \text{GABA}_B \) channels (for inhibitory pre-synaptic neurons). The synaptic conductances are described by a first-order linear kinetics \( \dot{g}_x = -g_x/\tau_x \) (where \( x = \text{AMPA}, \text{NMDA}, \text{GABA}_A, \text{GABA}_B \)) with \( \tau_{\text{AMPA}} = 1 \) ms, \( \tau_{\text{NMDA}} = 100 \) ms, \( \tau_{\text{GABA}_A} = 6 \) ms, \( \tau_{\text{GABA}_B} = 150 \) ms. When a pre-synaptic neuron fires an action potential, the synaptic conductance of the post-synaptic neuron increases in average by \( s_{\text{exc}} = 0.0085 \) or \( s_{\text{inh}} = 0.05 \) for excitatory or inhibitory connections respectively. The synaptic currents are then [70]:

\[
I_{\text{syn}}(t; n, m) = w_x(n) (g_{\text{AMPA}}(V_{\text{exc}} - V(t, n)) + \\
+ g_{\text{NMDA}} \left( \frac{(V(t, n) + 80)/60)^2}{1 + [(V(t, n) + 80)/60]^2} (V_{\text{exc}} - V(t, n)) \right) + \\
+ g_{\text{GABA}_A} (V_{\text{inh}} - V(t, n)) + \\
+ g_{\text{GABA}_B} (V_{\text{inh}} - V(t, n))
\]

(1)
where $w(n)$ represents a modulatory homeostatic factor (see below), the conductances are $g_{AMPA} = 1$, $g_{NMDA} = 2$, $g_{GABA_A} = 1$ and $g_{GABA_B} = 0.1$, $V_{exc} = 0 \text{ mV}$, $V_{inh} = -90 \text{ mV}$ are the reversal potentials for excitatory and inhibitory synapses respectively. Neuron receive excitatory input from a $5 \times 5$ neighborhood and inhibitory input from a $3 \times 3$ neighborhood with periodic boundary conditions. In any simulation run, parameters of the Izhikevich model as well as synaptic strength $s_{exc}$ and $s_{inh}$ were chosen at random following a normal distribution with standard deviation equal to 5% of the average value.

**Model for the generation of slow-wave oscillations.**

At the network level, slow waves oscillations are thought to reflect a periodic transition between an active “UP” state and a quiescent “DOWN” state. To simulate elevated firing activity of the UP state we increased the level of intrinsic excitability of neurons by increasing the variable $b$ in Izhikevich’s voltage equation [69]. If firing rate in such an active UP state is very high then a variety of factors may contribute to a gradual decay of neuronal excitability. Thus, we made the dynamics of this variable $b$ activity-dependent to reflect a negative feedback. Specifically, in our model the instantaneous firing rate of a neuron modulates the excitability of that same neuron as follows:

$$b(t) = b_{max} - mR(t)$$

where $b_{max}$ is the value of the parameter $b$ in steady state conditions (0.25 and 0.28 for excitatory and inhibitory neurons respectively); $R$ reflects the neuron’s firing rate (low-pass filtered spike train with time constant 0.9 s) and $m$ is a proportionality constant (set in the simulations to 6). Physiologically, such a negative feedback on excitability with this time scale has been variably ascribed to neuromodulators (acetylcholine, norepinephrine), ionic concentrations (potassium and calcium), ionic channels (Ca$^{2+}$-dependent potassium channels, persistent sodium channels) or metabolic support.

**UP/DOWN states can result from activity-dependent slow recovery dynamics in a balanced excitatory/inhibitory network.**

The negative feedback on excitability down-regulates excitability so that the active UP state is eventually exhausted and comes to an end. The network thus enters a quiescent state with little, if any activity. This DOWN state persists until $b$ recovers, at which point any small perturbation can jump-start the UP-state, propagating like an avalanche through the network[71]. This network model reproduced the regular UP and DOWN states transitions typical of slow-wave oscillations (Figures 2.B.2). In the network model we take the post-synaptic currents averaged across all neurons as a measure of local-field potentials (LFP) – since physiological LFPs are thought to reflect synaptic activity. With the present parameter settings the frequency and bandwidth of the network LFP was in the range of 0.5–1 Hz (Figure 5.A.1). This is the dominant band of slow-wave activity (0.5–4 Hz) in the human EEG (Figures 5.A.2) and is referred to as slow-wave oscillation [38]. For Figures 3 and 4 the LFP was estimated in four subregions of the network (in arrays of 11×11 neurons) and each LFP treated analogously to the multiple electrodes in the EEG. From these LFPs power and spatial coherence were calculated in the same way than the EEG data.
Figure 5. Slow waves features in the computational model.

A.1: Simulated local field potentials (LFP) in the computational model (low-pass filtered, cutoff frequency 2.5 Hz). A.2: Human EEG signal during slow-wave sleep (low-pass filtered, cutoff frequency 2.5 Hz). B: Dependence on excitatory connections strength of firing rate during the UP and DOWN states (B.1), power (B.2), main frequency (B.3) and coherence (B.4) of slow-wave oscillations (n = 5 simulations per data point, error bars indicate standard deviation). C.1: Example of auto-correlation of slow waves in the human EEG experiments (average of 5 subjects). C.2: Auto-correlation of simulated slow waves increasing the strength of excitatory connections. D: Example of simulated slow waves oscillations in the case of high synaptic connection strength ($S_{exc} = 0.1$).

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Power and coherence of slow-wave oscillations depend on synaptic strength.

In the model the firing rate during the UP states and the power of slow-waves depend strongly on the strength of excitatory connections, $S_{exc}$ (Figures 5.B.1–5.B.2). The configuration of parameters chosen here simulated UP states with an average firing rate of $\sim$5 Hz, compatible with slice experiments (2–10 Hz, [27]). Stronger excitatory connections would produce higher firing rate and stronger power of slow-waves, but the parameters where chosen to replicate the irregular EEG rhythms, as seen in Figure 5.A.2. In particular, while the frequency of the oscillations does not depend strongly on the range of excitatory connections (in the 0.5–1 Hz range, Figure 5.B.3), a critical characteristic of slow-wave oscillations in human EEG data is the short coherence time ($\sim$3 cycles, measured from the EEG data, Figure 5.C.1). The strength of excitatory connections ($S_{exc} = 0.0085$) was chosen to reproduce the short coherence time of EEG data (Figure 5.B.4–5.C.2). Increasing the strength of excitatory connections allows to reproduce the strongly regular pattern typical of slow-wave activity induced in brain slices (Figure 5.D).
Model of effect of electric field.

Most somata of inhibitory neurons remain largely unaffected by extracellular fields due to their symmetric location between dendritic arbors [31]. In contrast, somata of asymmetric pyramidal cells are incrementally polarized by uniform extracellular fields proportionally to the applied field magnitude \( E \) [47], [48]:

\[
\Delta V = k_E E
\]

where \( k_E \) is the sensitivity of the membrane to the field and depends on cell geometry and field orientation. We simulated here the effects of the field as a current injection to each excitatory neuron. This approach has been already successful in describing the effects of weak fields on gamma activity in rat hippocampal slices [19] and on slow waves in ferret cortical slices [28]. A capacitive term in Izhikevich's model converts this current input into a low-pass filtered membrane voltage response. Specifically, a current \( I_E \) results in a steady-state incremental polarization \( \Delta V \) above the resting membrane potential. With the present parameters the relationship between injected current and induced polarization was measured as \( \Delta V = (0.64 \pm 0.02) \cdot I_E \) where \( \Delta V \) is in mV. We assume that a 1 V/m electric field can polarize the soma by 0.2 mV (\( k_E = 0.2 \) mm, typical value for rat hippocampal pyramidal cells). With this we can estimate the relationship between electric field and applied current

\[
E = \frac{1}{0.2} \cdot \Delta V = 5 \cdot (0.64 \pm 0.02) \cdot I_E
\]

All figures use this conversion term when displaying values of electric field.

The total input current \( I \) to the \( n \)-th neuron is then given by:

\[
I(t,n) = \begin{cases} 
\sum_m I_{\text{syn}}(t,n,m) + I_E(t), & \text{for } n \text{ excitatory,} \\
\sum_m I_{\text{syn}}(t,n,m), & \text{for } n \text{ inhibitory}
\end{cases}
\]

Model for homeostatic plasticity.

There are different known types of homeostatic plasticity, involving different possible mechanisms [10]. The plasticity considered here affects the excitatory synaptic connections based on the firing rate of the post-synaptic neuron \( n \) [72],

\[
\tau_w \frac{\partial W_s}{\partial t}(t,n) = -w_s(t,n)(r(t,n) - r_t),
\]

where \( W_s \) is a factor that modulates excitatory synapses only, \( \tau_w \) is the time constant of this long-term process (minutes), \( r(t) \) is the instantaneous firing rate of the post-synaptic neurons computed as the inverse of the inter-spike interval (ISI) and \( r_t \) is the target firing rate. This homeostatic rule states that inputs to a post-synaptic neuron that is spiking faster than the target firing rate become weaker, while inputs to neurons not firing enough become stronger. The values of the constant were chosen as \( \tau_w = 400 \) s and \( r_t = 1 \) Hz. These values were chosen to reproduce changes of SWO power comparable with those measured during the night in the human EEG experiments.

Finite Element Model of transcranial electrical stimulation

The FEM computations follow a previous study [18]. Briefly, an anatomical MRI with 1 mm resolutions for an adult male was segmented and different tissues (gray matter, white matter, cerebrospinal fluid, skull, scalp, eye region, muscle, air, and blood vessels) were assigned conductivity values from the literature. Virtual electrodes were placed as in the human experiment and a finite-element mesh was generated. To compute electric field distribution in the brain the Laplace equations with Neumann boundaries were solved in COMSOL Multiphysics.
4.2 (Burlington, MA) with electrodes drawing 0.26 mA. The radial component of the resultant electric field was computed as the dot product of field vectors with a unit vector that is normal to the cortical surface. These radial components were collected in a volume of a 35 mm diameter around each EEG electrode (Figure 6.A shows radial fields at mesh points of the FEM within such a volume). These values were then sorted (Figure 6.B) and the resulting field profile was applied along one direction of the 2D network lattice (Figure 6.C). The top and bottom 3.12 percentile were exclude and amplitudes scaled to an average of 0.93 V/m.

Figure 6. Workflow to use the FEM analysis with the computational model.
A: Example of distribution of the normal component of the electric field under the electrodes considered in the FEM analysis (in this case Pz electrode). B: Radial field magnitudes in A were sorted and sampled in 30 location (3.12 percentile extremes were excluded). C: The sampled electric fields are then used for each column of neurons in the 2D lattice of the network model. doi:10.1371/journal.pcbi.1002898.g006

The fields computed by the FEM are significantly smaller than what we used in the network simulations. However, there are a number of parameters that may magnify the specific effect size. The polarization of the cell membrane in response to applied fields used here was based on in-vitro experiments in rat [48]. Human cortical cells are larger, which may result in larger membrane polarizations [31]. More importantly, we observed for the present model that the effect of polarization on network firing rate is an increasing function of the number of incoming synaptic connections (Figure 7). A realistic network architecture with hundreds if not thousands synaptic inputs is thus expected to lead to a larger effect size.

Figure 7. The effects of electric fields on firing rate depend on synaptic connectivity.
Normalized change in the average neuronal firing rate as a function of the number of neurons in the network model (A) or the numbers of pre-synaptic excitatory inputs (B). C: Same than
in B but with constant total synaptic input. Effect of fields on firing rate depends on number of input synapses and not network size.
doi:10.1371/journal.pcbi.1002898.g007

Supporting Information

Figure S1.tif

Example traces of the analysis performed on the EEG data. The decay of slow-wave oscillations was estimated by fitting (in a log-scale) power and spatial coherence after the stimulation (see Materials and Methods). A–B: Decay of the power of slow-wave oscillations during the night (Fz electrode, green: sham condition, red: stimulation condition) for two representative subjects.

Figure S2.
Entrainment of slow oscillatory activity by applying weak electrical stimulation. A: Coherence (mean vector strength, maximum = 1) between model LFP and applied slow-oscillating field as a function of field intensity and fractions of neuron polarized in either direction. B.1: Relative change of the duration of the DOWN state in the case of cathodal (blue) or anodal (red) stimulation (0.31 V/m). B.2: Relative change of the duration of the UP state in the case of cathodal (blue) or anodal (red) stimulation (0.31 V/m). C.1: Entrainment of slow-wave
oscillations immediately after the stimulation in the human EEG data (shown here for Pz electrode). The dark gray bar indicate the 10 s interval (delimited by the dashed magenta line) where the distribution of phases of the oscillations across trials and subjects is significantly different from being uniform. The same analysis performed on the following 10 s does not produce results statistically different from a uniform distribution (no preferential phase). **C.2:** Distribution of phases relative to figure C.1 considering all the trials and all the subjects. The 5 stimulation periods for all the subjects were aligned and the exponential decay from the AC-coupled amplifier was removed. The residual was fit to as sinusoid in frequency, phase and amplitude. Entrainment phase was only analyzed for the Pz electrode as this was the electrode with the smallest stimulation artifact. Note that the EEG recording equipment was AC-coupled resulting in a constant phase delay. Thus absolute value of phase is not relevant here. Nevertheless, a consistent phase across subjects despite anatomical differences is indicative of the predicted entrainment to a preferred phase.

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**Author Contributions**

Conceived and designed the experiments: DR LM LCP. Performed the experiments: DR LM LCP. Analyzed the data: DR FG AD LCP. Wrote the paper: DR MB LM LCP.

**References**

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Amping Up Brain Function: Trans-cranial Stimulation Shows Promise in Speeding up Learning: Scientific American

Posted on August 20, 2012 by John

Another group of researchers hot on the trail how tDCS might be used to enhance brain function is the (non-profit) Mind Research Network of Albuquerque, NM. A lot of their work is funded by NIH, but what I’ve seen around their tDCS research pertains to increasing soldier’s ability to detect danger, and is funded by DOA (2010 Research Report pdf). Unfortunately I was not able to find a full version of the paper not behind a pay wall. The abstract is here and from a Scientific America article...

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.

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.
A novel transcutaneous vagus nerve stimulation leads to brainstem and cerebral activations measured by functional MRI.

Author Information

Abstract

BACKGROUND:
Left cervical vagus nerve stimulation (VNS) using the implanted NeuroCybernetic Prosthesis (NCP) can reduce epileptic seizures and has recently been shown to give promising results for treating therapy-resistant depression. To address a disadvantage of this state-of-the-art VNS device, the use of an alternative transcutaneous electrical nerve stimulation technique, designed for muscular stimulation, was studied. Functional magnetic resonance imaging (MRI) has been used to test non-invasively access nerve structures associated with the vagus nerve system. The results and their impact are unsatisfying due to missing brainstem activations. These activations, however, are mandatory for reasoning, higher subcortical and cortical activations of vagus nerve structures. The objective of this study was to test a new parameter setting and a novel device for performing specific (well-controlled) transcutaneous VNS (tVNS) at the inner side of the tragus. This paper shows the feasibility of these and their potential for brainstem and cerebral activations as measured by blood oxygenation level dependent functional MRI (BOLD fMRI).

MATERIALS AND METHODS:
In total, four healthy male adults were scanned inside a 1.5-Tesla MR scanner while undergoing tVNS at the left tragus. We ensured that our newly developed VNS stimulator was adapted to be an MR-safe stimulation device. In the experiment, cortical and brainstem representations during tVNS were compared to a baseline.

RESULTS:
A positive BOLD response was detected during stimulation in brain areas associated with higher order relay nuclei of vagal afferent pathways, respectively the left locus coeruleus, the thalamus (left >> right), the left prefrontal cortex, the right and the left postcentral gyrus, the left posterior cingulated gyrus and the left insula. Deactivations were found in the right nucleus accumbens and the right cerebellar hemisphere.

CONCLUSION:
The method and device are feasible and appropriate for accessing cerebral vagus nerve structures, respectively. As functional patterns share features with fMRI BOLD, the effects previously studied with the NCP are discussed and new possibilities of tVNS are hypothesised.
Migraine patients find pain relief in electrical brain stimulation

This is not something new to the treatment of pain at all (immediate effects of tDCS on the µ-opioid system of a chronic pain patient) and has in fact been used for all sorts of chronic pain from fibromyalgia to neuropathic pain from chronic injury. The idea being to find the location in the brain that has been rewired by pain, pulse in this electrical current, and the areas can be in effect changed to respond differently over the treatment period. For certain types of injuries the research has been promising and it will be interesting to see if it can be useful in conditions where more areas of the brain are being stimulated and affected, such as migraines... the area being stimulated that seems to help with this treatment is the motor cortex.

“Researchers from the University of Michigan School of Dentistry, Harvard University and the City College of the City University of New York used a noninvasive method called transcranial direct current stimulation (tDCS) as a preventative migraine therapy on 13 patients with chronic migraine, or at least 15 attacks a month. After 10 sessions, participants reported an average 37 percent decrease in pain intensity.

The effects were cumulative and kicked in after about four weeks of treatment, said Alexandre DaSilva, assistant professor at the U-M School of Dentistry and lead author of the study, which appears in the journal Headache.

“This suggests that repetitive sessions are necessary to revert ingrained changes in the brain related to chronic migraine suffering,” DaSilva said, adding that study participants had an average history of almost 30 years of migraine attacks."
Research Shows Music Improves Brain Function

For most people music is an enjoyable, although momentary, form of entertainment. But for those who seriously practiced a musical instrument when they were young, perhaps when they played in a school orchestra or even a rock band, the musical experience can be something more. Recent research shows that a strong correlation exists between musical training for children and certain other mental abilities.
Cranial electrotherapy stimulation (CES): A safe and effective low cost means of anxiety control in a dental practice

Reducing patient anxiety always has been a concern in the practice of dentistry. Today, dentists have a variety of modalities available to reduce patients' anxiety. Typical examples include medication, electronic anesthesia, acupuncture, hypnosis, air abrasion dental handpieces, and nitrous oxide. Each has its advantages and disadvantages. Concerning disadvantages, some are too expensive, some are too time-consuming, and some have a long learning curve. Others are limited by patients' medical conditions or have lingering side effects after treatment.

A popular dental anxiolytic is nitrous oxide, a gas of low anesthetic potency that is incapable of inducing deep levels of anesthesia if an adequate oxygen concentration is maintained. Nitrous oxide induces a state of behavioral disinhibition, analgesia, and euphoria. Physicians and dentists have long considered nitrous oxide to be a safe pharmacological agent. Nevertheless, there is some evidence that its excessive or prolonged use can damage the bone marrow and nervous system by interfering with the action of vitamin B<sub>12</sub>.

There have been reports of immunological and reproductive disturbances in health care professionals who are chronically exposed to nitrous oxide. An elevated risk of spontaneous abortion has been seen among women who worked with nitrous oxide for three or more hours per week in offices not using scavenging equipment (relative risk = 2.6, 95 percent confidence interval 1.3–5.0, adjusted for age, smoking, and number of amalgams prepared per week), but not among those using nitrous oxide in offices with scavenging equipment.

It has been known for some time that electrical stimulation affects physiological changes. In the 1800s dentists reported excellent results using crude electrical devices for pain control. By the turn of this century, electrical devices were in widespread use to manage pain and to cure everything from cancer to impotency. The unrefined early electrical technologies and financial strength of the young pharmaceutical industry caused this form of therapy to fall into disrepute in the medical and dental professions. This left chemistry the "master science" and, as such, fully responsible for treating all of mankind's ills.

Now that we are approaching the turn of another century, armed with a new foundation of scientific data about the role of biophysics, scientists and practitioners are reexamining the use of electromedical modalities. One of the results is that over the past 30 years, transcutaneous electrical nerve stimulation has become widely accepted by physicians and dentists as a means to control many forms of pain.

Alpha-Stim (Electromedical Products International Inc., Mineral Wells, TX) cranial electrotherapy stimulation (CES) technology appears to offer an easy to use, safe, and cost-effective treatment to reduce situational anxiety. Stanley et al. showed that CES...
THE USE OF CRANIAL ELECTROTHERAPY STIMULATION TO BLOCK FEAR PERCEPTION IN PHOBIC PATIENTS

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1Life Balance International, Draper, Utah and 2Private Practice Consultant, Huntington Beach, California

ABSTRACT

Cranial electrotherapy stimulation (CES) involves small pulses of electrical current (1.5 mA or less) across the head. It is a known treatment for depression, anxiety, and insomnia. Chance clinical observations suggested that CES might be effective in reducing fear perception in phobic patients. This study was designed to investigate this possible effect. Thirty-one persons responded to public media announcements requesting subjects for a phobia treatment project. They were asked to imagine themselves in their worst phobic situation, then rate their fear on a scale from no fear to extreme fear. They were then given 30 minutes of CES, after which they were asked to frighten themselves again and to rate the fear as before. The patients were successful in generating a fear response, which, in turn, appeared to be mitigated by CES.

INTRODUCTION

Among the approaches for the treatment of fear in phobic patients, varied success has been claimed for biofeedback,1,2 desensitization,3,4 aversion relief,5 and combinations of behavior and/or cognitive therapies,6 including relaxation therapy.7 All of these are time consuming and require great attention to detail by the patient and therapist alike.

The treatment of phobic patients can be a long and taxing process for the physician or other therapist. Among pharmaceutical approaches, antidepressant drugs are said to be of particular benefit,8 as is at least one cardiovascular medication.9 However, even the newer tricyclic antidepressants are not without their risk to the patient, requiring the physician to be conscientious in the regulation of dosage and alert to the numerous possible negative side effects.10 They may also take days or weeks to begin to be effective.

Recently, the authors serendipitously observed that cranial electro-
Brain stimulation promises 'long-lasting' maths boost

The brain stimulation technique could help children who struggle with arithmetic, say researchers.

Applying high-frequency electrical noise to the brain can boost maths skills up to six months later, say Oxford University researchers.

A small study in Current Biology suggests the brain stimulation technique makes neurons function more efficiently. It could help those suffering with neurodegenerative illness, stroke or learning difficulties. An expert said the technique could have “real, applied impact.” Transcranial random noise stimulation (TRNS) involves applying random electrical noise to targeted areas of the brain by placing electrodes on the surface of the scalp. It is a relatively new method of brain stimulation which is painless and non-invasive.

Our neuro-imaging results suggested that TRNS increases the efficiency with which stimulated brain areas use their supplies of oxygen and nutrients.”

Dr Roi Cohen Kadosh, University of Oxford
Brain stimulation promises 'long-lasting' maths boost

Effects of CES Math Stimulation can Last 6 Months

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Electric shock treatment 'cures memory loss', scientists claim

Giving a person an electric shock can help improve their memory, scientists have discovered.

"As we age, the connections between the neurons in our brains weaken."

Researchers found that a tiny surge of power to parts of the brain can improve recall memory by 11 per cent.

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The treatment stimulates certain neurons in the brain so when a person tries to retrieve a name from their brain, they suddenly start working.

If developed, it could provide treatment for stroke victims as well as people whose memory fades through old age or even old age.

The study, from Temple University, Philadelphia, could also offer solutions to those who suffer the embarrassing situation of forgetting a person's name.

"We know a lot about how to make people's memory worse, but we don't know very much about how to make people's memory better," said Ingrid Olsen, a psychologist who led the study.

"These findings hold promise because they point to possible therapeutic treatments for memory rehabilitation following a stroke or other neurological insult."
CRANIAL ELECTROTHERAPY STIMULATION (CES)

Cranial electrotherapy stimulation (CES) is the use of low intensity microcurrent (under one milliampere) to stimulate various parts of the brain in an effort to achieve neurochemical changes as an alternative to drug therapy. It is widely used as a treatment for insomnia, depression, and anxiety, but has also been proposed as an alternative intervention for children with autism and ADHD. Cranial electrotherapy stimulation is also known by several other terms, including neurofeedback, microcurrent electrical therapy, electroconvulsive treatment, and electrosleep. This treatment is non-invasive, and involves placing electrodes on or near the ear while a hand-held device produces the electrical current that travels to the brain. Various protocols exist, but typically the stimulation is provided daily for a period of two to three weeks, and is then provided on a less frequent basis. Children are able to read, watch television, or listen to music during the therapy. Effects are generally immediate, but are also cumulative, so it is important to maintain the recommended protocol to achieve the full benefits of the therapy.

The theory behind CES is that the microcurrent travels to the brainstem and activates nerve cells that produce the neurotransmitters serotonin and noradrenaline. These chemicals are linked to relaxation and to the inhibition of arousal and agitation. Their release is believed to help the brain to create an alpha wave rhythm, which promotes mental focus and relaxation.

Patients often describe the sensation of CES to be pleasant, and to help them to immediately feel relaxed and more mentally alert. They often report a tingling or pulsing sensation in the earlobe which is not painful. Side effects are few, and may include mild headaches, lightheadedness, or skin irritation from the electrodes. Rarely, more serious side effects have been reported, including sleep disturbances, excessive excitement, or an increase in anxiety.

In the United States, the Federal Food and Drug Administration (FDA) approves cranial electrotherapy stimulation for the treatment of insomnia, depression, and anxiety, but not for other medical conditions including pain management, chemical dependency, autism or ADHD. Because physicians are not typically trained in its use, and continuing education opportunities are limited, this treatment is often recommended by psychologists or alternative health providers who may not have a full understanding of the medical and neuropsychological implications of these conditions. Critics express concern that CES treatment focuses on alleviating a set of symptoms, rather than addressing the underlying condition.
Validation and Verification of Claims is the LAW

WHPRS EDUCATOR
Rating +11
science, registrations
publications, medical
textbook, university
taught, government
licenses to use

EDUCATOR
THE EDUCATOR
IS THE MOST
RESEARCHED
ENERGETIC
MEDICINE DEVICE
IN HISTORY
SCIO/Eductor Device rating is the highest = Platinum

11 European Governmental Professional Work Qualifications for using the device. Platinum rating. [X]

10 Taught in accredited medical universities and your device/product appears or your peer reviewed medical studies are quoted in certified medical textbooks. This takes a minimum of seven years in peer reviewed medical journals. Gold rating. [X]

9 Medically supervised, independently researched, double blinds, Peer reviewed medical journal publication Silver rating. [X]

8 Double Blind Independent Medically Supervised Studies. [X]

7 Independent Medically Supervised Studies. [X]

6 TESTIMONIALS, STORIES OR clinical studies done by your personal staff. Proper Ethics Committees and or Institutional Review Boards are needed, as well as informed consent and full compliance with the Helsinki research accord. [X]

5 SCIENCE + DEVICE STUDIES+ SAFETY Registration+ MEDICAL CLAIM Registration- here your device/product is proven safe, and effective for medical uses in the claims you specify in your registration. [X]

4 SCIENCE + DEVICE STUDIES+ SAFETY Registration- here your device is safety tested to CE standards [X]

3 SCIENCE + DEVICE STUDIES- bench tested for performance specs [X]

2 SCIENTIFIC THEORY- accepted science [X]

1 MAGICAL THINKING SCIENCE- here pseudo-science, unproven theories [ ]

0 DIVINATION- the device uses subtle muscle control of the therapist [ ]

-1 FRAUDULENT-STOLEN – Completely Illegal [ ]

http://www.worldhealthproductservice.com/index.html
The SCIO device can use the Trivector and Cybernetic Loop to rectify aberrant and disharmonious energy patterns in the body. This has profound effects on all body functions but affects the corpus callosum most intensely.

This means that the ability of the conscious verbal mind to relate to the subconscious is increased with the rectification process. The patient will probably not feel the effect. There will always be a positive effect. If there is a negative effect, it is because there is shielded or covert feelings or memories in the subconscious. These will cause disease if left untreated. A simple release may solve the problem.

The changes include:

1. Activate the innate intelligence to balance the body energies. This is the basic principle of chiropractic, acupuncture, and osteopathy medicine.

2. There is an easier exchange of energy and information from right brain to left brain via the corpus callosum. The corpus callosum is the largest energy form in the body and the rectification process has profound effects on stabilizing it, so it dramatically reduces switching phenomena.

3. The SCIO thereby increases the ability of the conscious to interface with the unconscious. This allows greater knowledge of self and of the higher self.

4. There is a greater memory access, a more true access of memory without emotional clouding.

5. There is a greater flexibility of connective tissue, allowing for more resilience.

6. There is a greater oxygenation and hydration ability of the body.

7. There is a smoother muscle control.

8. There is a general increase in well being that the conscious mind is so often unable to perceive. And thus there are thousands of subtle improvements to be found.

EDUCTOR AN ADVANCE IN SCIO TECHNOLOGY

If you need more information on the SCIO and purchase details please get in touch with us

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pictures on China, AC Milan, San Antonio spurs, Dennis Johnson

The first sport study with the Quantum Xrroid technology was on members of the Cleveland Browns football team in 1988. The results were amazing and all of the participants went all Pro over the next five years. Having worked with the power lifting team of Hungary in 1991 they went from moderate to gold medal performance.

AC Milan bought some systems and their injury level dropped 91%. This was because the system can stimulate and accelerate healing of injured tissue. They asked for us to develop the device to sharpen the athletic skills of the clients. With this in mind we developed a way to sharpen coordination, endurance and strength. AC Milan won the European championship the next two years. We worked with Dennis Johnson ex twice NBA MVP in the San Antonio Spurs system. The results were amazing.

The Chinese Olympic team had us do a study. Out of their 487 athletes in the 2008 Olympic Games, they assigned 150 of the sick, old, weak, and tired to us. The study was to see if we could repair injured tissue and get an athlete back onto the field. The results were astounding. Out of the hundred medals won by the Chinese our 30% of the injured performers won 33% of the medals. Our athletes were not supposed to win. And because of this Desire’ was awarded an honorary Gold medal.

Sports medicine has entered the energetic arena. There are those who want to win and they differ from those who want to conform.

Some of the best cyclists in the world have used the SCIO to win championships.
USE EDUCTOR CES FOR FEAR, PHOBIA AND PARANOIA

EVIDENCE BASED

Sending in an auto-focused sophisticated pulse different for each patient based on their personal electrical needs.

If you need more information on the SCIO and purchase details please get in touch with us
Mandelay Kft.
| web: www.qxsubspace.com | e-mail: info@qxsubspace.com
EDUCTOR AN ADVANCE IN SCIO TECHNOLOGY

IT IS A SCIENTIFIC FACT THAT A LOW LEVEL VOLTAMMETRIC PULSE CAN INHIBIT PAIN SIGNALS.
The SCIO will let the patient’s body electric autofocus a harmonic pulse to maximize this effect. This is called micro-current transcutaneous electro-nerval stimulation and can help you to reduce pain while helping you find the cause...

If you need more information on the SCIO and purchase details please get in touch with us

Mandelay Kft
tel: +36 21 252 3503
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e-mail: info@qxssubspace.com
The Eductor is a registered EEG Biofeedback Device measuring the Electro-EncephaloGraph of each side of the Brain

CPT Code-- 90901

Recommended for Emotional Evaluations
As we increase Osmosis with Quantum Eductor Biofeedback and we increase the VARHOPE or Electrical Vitality then Everything works better, and then things start to get done that were not functioning before. We should Not be surprised.
Clinical Evaluation

Eductor

Measures & Treats

- Volts and Oscillations (EMG, EEG)
- Amps and Oscillations (ECG)
- Resistance (GSR)
- Hydration
- Oxidation (Redox potential)
- pH acid vs alkalinity
- Reactivity evoked potential to voltammetric fields of substances (TVEP) over 228,000 measures a second of these energetic factors
- Brain wave and emotions with (MCES)
- Pain with (MENS) (TENS)
- Trauma or wounds (EWH)
- Electro Weakness Ph, Redox disorder (VARHOPE Correction)
- Trickle charge the body electric

All designed to detect + reduce Electro-stress and Balance the Body Electric Automatically
Healthy membrane potential and adequate body voltage makes all of the functions of the cell work better.

Low Body Voltage leads to weak membrane potential, weak osmosis, trapped toxins, premature aging, and increased susceptibility to virus.

Eductor and SCIO Technology

Charging the Human Battery

Factors that influence the body voltage and membrane potential are fatty acids in the cell membrane, minerals, especially salts, hydration water, oxygenation, stress, toxins and life style.

The SCIO has been proven in tests to increase the electrical potential of the body. Increased cellular membrane potential makes osmosis increase, which increases detoxification, nutrient transfer and absorption, hydration, oxidation, and all cellular functions in general.

If you need more information on the SCIO and purchase details please get in touch with us

Mandelay KT

tel: +36 21 252 3503 | web: www.qxsubspace.com | e-mail: info@qxsubspace.com
Spinal injury and pain

Using MTENS, and TVEP the SCIO can treat the spinal area for injury and pain. Sending in an auto-focused sophisticated pulse different for each patient based on their personal electrical needs.

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Mandelay Kft.
tel: +36 21 252 3503 | web: www.qxsubspace.com | e-mail: info@qx-subspace.com
There is published research on these therapies. The new world of energetic medicine can help you.

It is scientific fact that when a low level voltage and micro-current pulses are applied to the body, it is possible to induce proper brain activity and healing. The SCIO will test the body's bio-electric fields and provide feedback on the state of health. MCES for Autism is a treatment that has been shown to be effective in helping children with autism. It is believed that the treatment helps to normalize brain function and improve symptoms such as hyperactivity, aggression, and anxiety.

For more information on the SCIO and purchase details, please contact Mandelay Kft.

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Eductor

The word 'Doctor' comes from the Latin word 'Eductor' which means 'to teach'.

Thomas Edison said that the doctor of the future will teach the patient how to live and how to eat, exercise and meditate.

The Eductor is a Biofeedback Teacher

WE CAN HELP YOU TO INCREASE YOUR WELLNESS NATURALLY

PROFESSOR DESIRÉ DUBOUNET
THE DEVELOPER