Role of Transcranial direct current stimulation in Neurological Disorders

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Ahmed Taher Mashali

Contents

list of abbreviations

AD: Alzheimer’s disease.

atDCS: Anodal transcranial direct current stimulation

BCM: Bienen stoke-Cooper-Munro rule

CSF: Cerebrospinal fluid

ctDCS: Cathodal transcranial direct current stimulation

DBS: Deep brain stimulation

DLPFC: Dorsolateral prefrontal Cortex

ECT: Electroconvulsive therapy

fMRI: Functional magnetic resonance

JTT: Jabson-Taylor test

LH: Left hemisphere

LTD: long term depression

LTP: Long term potentiation

M1: Primary motor area

MRS: Magnetic resonance spectrography

NIBS: Non-invasive brain stimulations

NRS: Numerical rating scale

PD: Parkinson disease

PMC: Premotor cortex

list of abbreviations

rCSF: Regional cerebrospinal fluid

S1: Primary sensory area

SCI: Spinal cord injury

SMA: Supplementary motor area

tDCS: Transcranial direct current stimulation

TC: Temporal cortex

TMS: Transmagnetic stimulation

WM: Working memory

list of abbreviations

Introduction

Transcranial direct current stimulation (tDCS) is a form of neurostimulation is used as therapy for certain neurological disorders.the transcranial application of weak direct current is an effective and relative simple method to polarize brain regions. Transcranial direct current stimulation(tDCS) has been demonstrated to modulate human cerebral cortical functions inducing focal, prolonged, but reversible shifts of excitability***(Nitsche et al., 2003)***.

Previous studies in animals have used intracortical or epidural electrodes to stimulate the brain. In the past few decades, however, transcranial application of low amplitude direct currents demonstrated to induce intracerebral current flow sufficiently large enough to be effective in altering cortical neuronal activity***(Hummel et al., 2008)***.

The efficacy and duration of the tDCS-induced excitability changes in humans depend on length of the stimulation, size of the electrodes, and strength of the current***(Borckardt et al.,2012)***.

Whereas polarity is determined by the orientation of the electric field. For example, anode over the motor cortex and cathode over the contralateral supra-orbital region produces a lasting increase in motor cortical excitability when the current is applied for several minutes.In contrast, when the electrodes are reversed, a decrease in motor cortical excitability is seen***(Nitsche et al., 2008)***.

Neuroplasticity is defined as any enduring change in cortical properties caused by environmental changes, lesions, or functional adaptation to new circumstances. It refers to the ability of the brain to change throughout life based on experiences***(Liebetanz et al., 2009)***.

The way that transcranial direct current stimulation functions could be due to the plasticity concepts of long term potentiation and long term depression since the two share some basic similarities. Long term potentiation (LTP) is the strengthening between two neurons while long term depression (LTD) is the weakening between two neurons. These effects are achieved mainly by alteration of synaptic transmission ability through modifications of intracellular cAMP and calcium levels. Also, both LTP, LTD, and the effects of tDCS are protein synthesis dependent. It is for these reasons that LTP and LTD are proposed mechanisms of the function of tDCS***(Michael et al., 2003).***

Clinical therapy using tDCS may be the most promising application of this technique. There have been therapeutic effects shown in clinical trials involving Parkinson's disease, tinnitus, fibromyalgia, and post-stroke motor deficits***(Norris et al.,2010).***

A growing body of research demonstrated modulation of behavior after tDCS application in the motor , somatosensory, visual, and cognitive domains in healthy volunteers and neuropsychiatric disorders***(Boggio et al.,2006)*** .

Aim of the work

- To know what is the transcranial direct current stimulation (tDCS).
- The effects of tDCS on neuroplasticity.
- The role of tDCS on different neurological disorders.

Transcranial direct current stimulation (tDCS)

Introduction about brain stimulation ways:

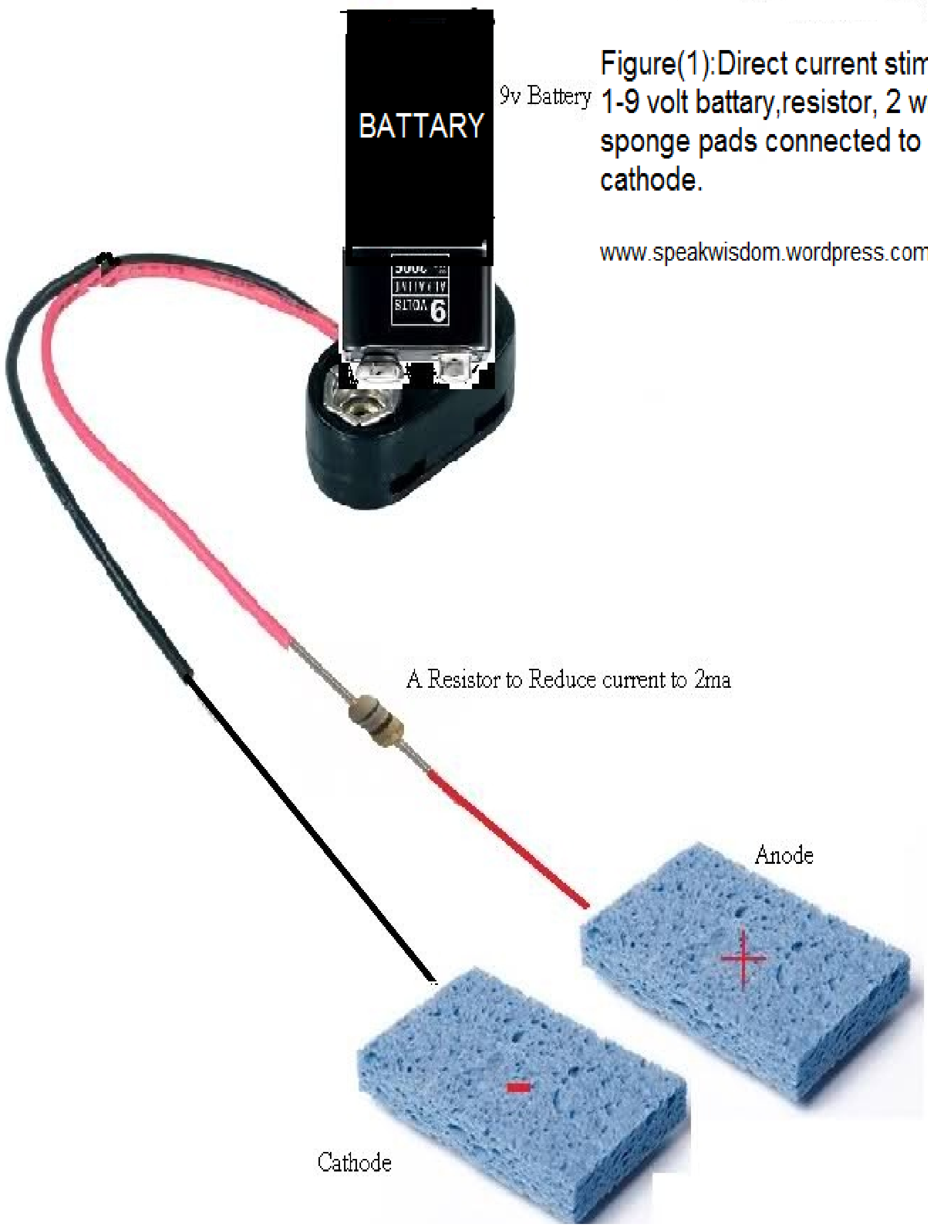
1-Electroconvulsive therapy (ECT): is the oldest and the best known and, in fact, is still recognized as the most effective treatment for severe depression. It involves the application of brief electrical pulses to the scalp to induce seizures throughout the brain. The seizures appear to relieve depression by increasing the release of brain chemicals such as serotonin and dopamine***(Kringelbach et al.,2007).***

2-Transcranial magnetic stimulation (TMS): involves the placement of an electromagnetic coil on the scalp. The coil is not implanted, so no anesthesia is necessary; nor is it necessary to induce seizures (as with ECT). A pulsed high-intensity current is passed through the coil into specific areas of the brain, creating a powerful magnetic field that changes the way brain cells function***(García et al.,2008).***

3-Deep brain stimulation(DBS): is a neurosurgical procedure involving the implantation of a medical device called a brain pacemaker, which sends electrical impulses, through implanted electrodes, to specific parts of the brain (brain nucleus) for the treatment of movement and affective disorders***(U.S. Department of Health and Human 2008).***

4-Transcranial direct current stimulation (tDCS):

It is defined as a form of neurostimulation which uses constant, low current delivered directly to the brain areas via small electrodes(***Dimova et al.,2010***).



Figure(1):Direct current stimulation device 1-9 volt battary,resistor, 2 wires and 2 sponge pads connected to anode and cathode.

www.speakwisdom.wordpress.com\2012\8\27-tdcs

History & Discovery:

The basic design of tDCS is using direct current to stimulate the area of interest, has been around for over 100 years. There were a number of rudimentary experiments completed before the 19th century using this technique that tested animal and human electricity. It was due to these initial studies that tDCS was first brought into the clinical scene. In 1804, Aldini started a study in which he used the technique of direct current stimulation and was successful in improving the mood of melancholy patients. Unfortunately, this discovery did not receive much attention and was forgotten in the light of other types of neurostimulation. When electric shock therapy was developed in the 1930s and was found to be a relatively effective treatment against depression therapy using tDCS was abandoned***(Sparing & Mottaghy 2008).***

Transition into modern scientific research:

There was a brief rise of interest in transcranial direct current stimulation in the 1960s when studies by the researcher Albert proved that the stimulation could affect brain function by changing the cortical excitability. He also discovered that positive and negative stimulation had different effects on the cortical excitability. Although these findings were important in the use of tDCS in therapy, research in this area was again dropped as drug therapy proved to be a more effective and simple method of therapy***(Datta et al. 2009)***.

It wasn't until recently that tDCS was rediscovered for a third time. This time, the rediscovery was fueled by an increase of interest and understanding of basic brain functioning as well as new brain stimulation and brain imaging techniques such as TMS(transmagentic stimulation) and fMRI(functional magnetic resonance imaging). Now,the transcranial direct current brain stimulation technique because safety protocol has shown that tDCS is extremely safe for human use***(Frohman et al.2012).***

Difference between tDCS and Transmagentic stimulation(TMS):

(TMS) is a noninvasive method to cause depolarization or hyperpolarization in the neurons of the brain. TMS uses electromagnetic induction to induce weak electric currents using a rapidly changing magnetic field; this can cause activity in specific or general parts of the brain with little discomfort, allowing for study of the brain's functioning and interconnections. According to the United States National Institute of Mental Health, TMS "uses a magnet instead of an electrical current to activate the brain. An electromagnetic coil is held against the forehead and short electromagnetic pulses are administered through the coil. The magnetic pulse easily passes through the skull, and causes small electrical currents that stimulate nerve cells in the targeted brain region. And because this type of pulse generally does not reach further than two inches into the brain, scientists can select which parts of the brain will be affected and which will not be ***(National Institute of Mental Health 2013).***

How does the tDCS work?

It consists of a battery and a current regulator, attached by wires to the scalp with two pad electrodes. And it works by sending constant, low direct current through the electrodes. When these electrodes are placed in the region of interest, the current induces intracerebral current flow. This current flow then either increases or decreases the neuronal excitability in the specific area being stimulated based on which type of stimulation is being used. This change of neuronal excitability leads to alteration of brain function, which can be used in various therapies as well as to provide more information about the functioning of the human brain***(Nitsche&Paulus 2000).***

Firue(2):Application of transcrainal Direct Current Stimulation device on the scalp to the area of interest.

http://www.drmueller-healthpsychology.com/tdcs.html

Types of stimulation:

There are three different types of stimulation: anodal ,cathodal, and sham. The anodal stimulation(atDCS) is positive (+Ve) stimulation that increases the neuronal excitability of the area being stimulated .Cathodal stimulation (ctDCS)is negative (-Ve) stimulation decreases the neuronal excitability of the area being stimulated. An example of how cathodal stimulation could be used is as a therapy for a psychiatric disorder caused by the hyper-activity of a particular area of the brain. Cathodal stimulation would decrease the neuronal excitability to reach a more stable level of activity. ***(Nitsche et al.,2003)***.

Sham stimulation is important because it is the control stimulation. This stimulation emits a brief current but then remains off for the remainder of the stimulation time. With sham stimulation, the person receiving the tDCS does not know that they are not receiving prolonged stimulation; this provides a control condition for experiments, which can be double-blinded. Without this type of stimulation, the effects of the positive or negative stimulation could not be proven***.(Paulus W. 2004).***

Effects on the brain:

One of the most important aspects of tDCS is its ability to achieve cortical changes even after the stimulation is ended. The duration of this change depends on the length of stimulation as well as the intensity of stimulation. The effects of stimulation increase as the duration of