THE TRANSCRANIAL STIMULATION WITH DIRECT CURRENTS (TDCS): AN HISTORICAL AND CONCEPTUAL MINIREVIEW

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ABSTRACT

Transcranial Stimulation with Direct Currents (tDCS) is a method for non invasive brain stimulation created to induce functional changes in cerebral cortex. tDCS consists of application on the scalp of electrodes providing a low intensity direct current influencing neuronal functions. tDCS is not the only neurostimulation method for neuroscience clinical practice and research and can be used for treat many different clinical conditions such as migraine prevention, autism spectrum disorders (ASD), cerebral palsy rehabilitation, post-traumatic brain injury neuropsychological disorders.

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Historical background

Transcranial Stimulation with Direct Currents (tDCS) is a method for non invasive brain stimulation created to induce functional changes in cerebral cortex. tDCS consists of application on the scalp of electrodes providing a low intensity direct current influencing neuronal functions. tDCS is not the only neurostimulation method for neuroscience clinical practice and research and can be used for treat many different clinical conditions such as migraine prevention(1; 2), autism spectrum disorders (ASD)(3), cerebral palsy rehabilitation(4; 5), post-traumatic brain injury neuropsychological disorders(6; 7).

In general, the study of the brain functioning different from mind dimension has always aroused great appeal in scientists in different century.

The effects of the current on brain have been objects of large interest, scientific or not, from the time of its discovery in different parts of the world. The effects of an uncontrolled brain stimulation in fact, have been reported since the past.

Scribonius Largus (the physicist of the Roman emperor Claudius)(8), described like placing a live torpedo on the head to send a fort electricity, the migraine could be relieved. Galen of Pergamum, one of the greatest physicians of the ancients(9), and Plinius the elder described similar results. In the eleventh century, Ibn-Sidah, a Muslim physicist, suggested to use an electric catfish to treat epilepsy(10). The transcranial stimulation methods therefore have a long tradition. Already around 1800, when Volta invented the electric battery, researchers began to study current applications directed in a variety of neurological disorders. Walsh in 1773, Galvani from 1791 to 1797 and Volta himself in 1792 established that the electrical stimulation of various length could provoke different effects[10] (Figure 1).

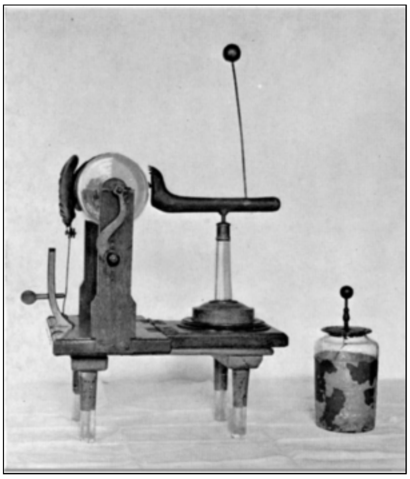

Fig. 1: An electrical machine for generating static charge designed by John Wesley, with Leyden Jar to the right. From R.V. Spivery 'A pictorial history of Wesley's Chapel and its founder.' London: Pitkin Pictorials; 1957 p.22.

The first systematic report of the clinical applications of galvanic current is date in this period, when Giovanni Aldini, the nephew of Galvani, and some other researchers used transcranial electric stimulation as a technique for treating depression. In Nineteenth century many other researchers used the galvanic current for the treatment of mental disorders, obtaining results that are not always satisfactory[11].

In Rockwell's 1896 The Medical and surgical use of electricity local treatment of specific hysterical symptoms is dismissed as 'unphilosophical and usually unsuccessful' except in hysterical aphonia, where 'any form of irritation, external or internal, electric or otherwise, may cause instantaneous cure'. For hysterical paralysis Rockwell advocated the general application of electricity to the whole body; although observing like many others that the response could be 'capricious and inconsistent', commenting 'In many instances general faradization promotes rapid recovery; other cases are very rebellious and only improve up to a certain point'[11] (Figure 2)

Looking at the most recent history, the use of electroconvulsive therapy and psychotropic drugs and lack of signals reliable neurophysiological obscures the use of direct current on the Central Nervous System as a therapeutic and research tool, especially in the field of psychiatry. However, the galvanic current continued to be used for the treatment of skeletal muscle disorders and peripheral pains.

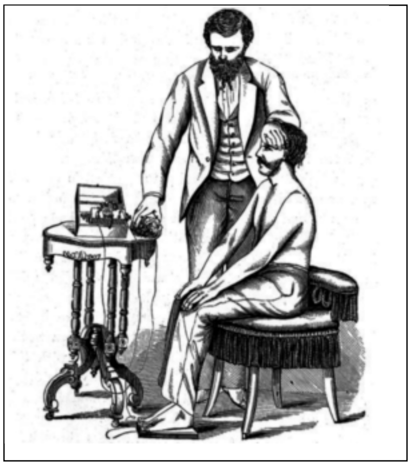

Fig. 2: General faradization. From J. Althaus, 'A Treatise on Medical Electricity' London: Longman; 1873.

When in 1998 it was possible to measure the effects application of direct current on the motor cortex, at the level non-invasive, by means of transcranial magnetic stimulation, the tDCS became reliable in terms of parameters such as the intensity of stimulation, duration and validation of its following plastic effects. Priori's studies and his colleagues[8] followed by those of Nitsche and Paulus[9; 10], proved as one weak direct current could actually be sent to the transcranic level going to induce bidirectional changes in the cortical dependent on polarization.

Specifically, it was noted that the anodic direct current increased cortical excitability, while the cathodic one decreased it.

The possible use was therefore envisaged of this technique in order to analyze plasticity and excitability cerebral, and as a valid cure in the field of neuropsychiatric disorders[11].

Physical and operating principles

The tDCS differs from other non-invasive stimulation techniques brain, such as transcranial electrical stimulation (TES) and the TMS[12], because this technique does not induce neuronal ignition by means of a supersaturated membrane depolarization neuronal, but rather it modulates the spontaneous activity of the neuronal network. The main and primary mechanism of action is a change (polarization), dependent on the polarity of the tDCS of resting membrane neuronal potential. So there is an intense effect of this low current in continue on cortical excitability. This effect, in some cases, can persist even up to a few hours after stimulation(11, 14, 15).

tDCS interferes with brain excitability through the modulation of intracortical and corticospinal neurons(11, 14, 15).

tDCS instrumentation

The tDCS instrumentation presents a rather simple structure compared to other types of brain stimulation devices. tDCS is mainly composed of two electrodes and a battery-powered device capable of supplying a constant and continue electrical flow. Since an electrical closed circuit has been created, the two electrodes correspond to a cathode and an anode. By placing them above the scalp, it is possible to modulate a particular area of the central nervous system. The positioning of the electrodes therefore takes on fundamental importance, and usually determined in agreement with the international EEG 10-20 system. To make a example, studies exploring the motor cortex place the electrodes above the zones C3 and C4. To create the homogeneous electric field responsible for the plastic effects of neural tissue, and therefore necessary for tissue analysis, it is usually made to flow inside the electrodes a direct current that can vary from 0.5 to 2 mA, for about 20-40 minutes. The tDCS can indeed be used in general to manipulate cerebral excitability by means of polarization of membrane: a cathodic stimulation hyperpolarizes, one Anodal stimulation depolarizes the resting membrane potential(11, 14, 15).

To In this regard, it is necessary to specify that the current flow is composed by ions present in the brain tissue and not superimposed by external source. Therefore the positive ions will tend to flow towards the cathode, while the negative ones will flow towards the anode. The flow comes conventionally considered to be directed from the anode to the cathode, creating a closed circuit in which the current passes through the head(11, 14, 15) (Figure 3).

There are two main types of electrode mountings, but different nomenclatures to define them. Therefore for reasons of clarity, it is now we need to discuss some terms used to describe the assembly of the tDCS. When an electrode is placed under the neck, the whole assembly is called unipolar, while the montages with the two electrodes on the head are identified as bipolar(11, 14, 15).

Although the electric fields produced by tDCS are relatively non focal points, the positioning of the electrodes is therefore critical. Eg, a study showed that by changing the reference of the electrode from the DLPFC (lateral dorsal prefrontal cortex) on the M1, were eliminated effects of tDCS on working memory (short-term memory). The same can be said for the phosphenes, which is modulated only during the occipital tDCS (visual cortex) and not during that performed on other areas. In the clinical setting, only the stimulation of the DLPFC and not of the occipital area led to a improvement of symptoms of major depressive disorder, further proof of the above. Different settings and positioning therefore, they result in distinct streams of current through the brain and therefore the ability to adjust the assembly allows the customization and optimization of tDCS for specifications applications(11, 14, 15).

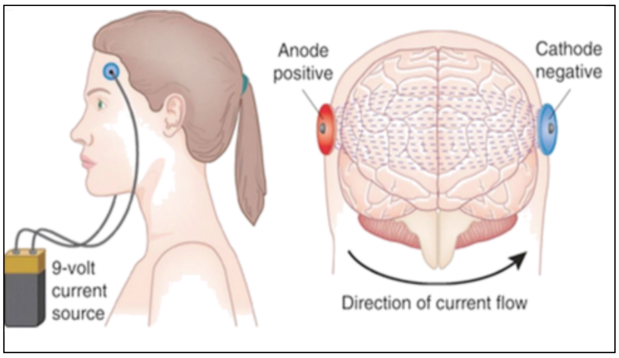

Fig. 3: tDCS electrodes al location on scalp.

In conclusion, tDCS may be considered as safety and efficacy therapy for many different disorders including neuropsychiatric and neurodevelopmental disorders as neurobehavioural or drugs therapy supporting(16-54).

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