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The role of transcranial direct current stimulation (tDCS) in rehabilitation of stroke patients with aphasia

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Transcranial direct current stimulation (tDCS) is a form of neurostimulation that uses constant, low direct current delivered via electrodes on the head.

It was originally developed to help patients with brain injuries or psychiatric conditions like major depressive disorders. tDCS appears to have some potential for treating depression. However, there is no good evidence that it is useful for cognitive enhancement in healthy people, memory deficits in Parkinson's disease and Alzheimer's disease, non-neuropathic pain, and non improving upper limb function after stroke.

tDCS appears to be somewhat effective for depression. There is also evidence that tDCS is useful in treating neuropathic pain after spinal cord injury and improving activities of daily living assessment after stroke.

The adverse effects associated with tDCS appear to be mostly limited to headaches and itchiness and redness at the site of stimulation. When applied following established safety protocols, transcranial direct current stimulation is widely regarded as a safe method of brain stimulation. Safety protocols limit the current, duration, and frequency of stimulation, thereby limiting the effects and risk.

There has been much work done in the last 10 years to develop a safety protocol for administering transcranial direct current stimulation. Many studies have been conducted to determine the optimal time of stimulation and current used as well as steps to take in order to reduce or eliminate the side effects felt by the person receiving the stimulation. Present safety guidelines on the research and medical fields treat daily stimulation up to 60 min and up to 4 mA as safe. However, the tolerability of every day application for more than 10 sessions per two weeks remains unclear.

There is no strict limitation on the duration of stimulation set at this point but a stimulation time of 20 minutes is considered the ideal time. The longer the stimulation duration, the longer the observed effects of the stimulation persist once the stimulation has ended. A stimulation length of 10 minutes results in observed effects lasting for up to an hour. It is generally encouraged to wait at least 48 hours to a week before repeating the stimulation. Also, it is advised to warn the person receiving the stimulation of the possible after effects of the tDCS stimulation.

There are a few minor side effects including skin irritation, a phosphene at the start of stimulation, nausea, headache, dizziness, and itching under the electrode. Nausea most commonly occurs when the electrodes are placed above the mastoid for stimulation of the vestibular system. There are several ways to reduce the skin irritation felt during stimulation. Electrodes may be prepared with saline solution and the skin prepared with electrode cream. Also, ramping up (slowly increasing) the current can reduce the irritation. It is not advised to administer this stimulation to people susceptible to seizures, such as people with epilepsy. However, seizures do not seem to be a risk for healthy individuals. One of the 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 stimulation increases or the strength of the current increases.

The way that the stimulation changes brain function is either by causing the neuron's resting membrane potential to depolarize or hyperpolarize. When positive stimulation (anodal tDCS) is delivered, the current causes a depolarization of the resting membrane potential, which increases neuronal excitability and allows for more spontaneous cell firing. When negative stimulation (cathodal tDCS) is delivered, the current causes a hyperpolarization of the resting membrane potential. This decreases neuron excitability due to the decreased spontaneous cell firing.

Transcranial direct current stimulation 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

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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.

Transcranial direct current stimulation is a relatively simple technique requiring only a few parts. These include two electrodes and a battery-powered device that delivers constant current. Control software can also be used in experiments that require multiple sessions with differing stimulation types so that neither the person receiving the stimulation nor the experimenter knows which type is being administered. Each device has an anodal, positively charged electrode and a cathodal, negative electrode. Current is conventionally described as flowing from the positive anode, through the intervening conducting tissue, to the cathode, creating a circuit. To set up the tDCS device, the electrodes and the skin need to be prepared. This ensures a low resistance connection between the skin and the electrode. The careful placement of the electrodes is crucial to successful tDCS technique. The electrode pads come in various sizes with benefits to each size. A smaller sized electrode achieves a more focused stimulation of a site while a larger electrode ensures that the entirety of the region of interest is being stimulated. If the electrode is placed incorrectly, a different site or more sites than intended may be stimulated resulting in faulty results. One of the electrodes is placed over the region of interest and the other electrode, the reference electrode, is placed in another location in order to complete the circuit. This reference electrode is usually placed on the neck or shoulder of the opposite side of the body than the region of interest. Since the region of interest may be small, it is often useful to locate this region before placing the electrode by using a brain imaging technique. After the stimulation has been started, the current will continue for the amount of time set on the device and then will automatically be shut off. Recently a new approach has been introduced where instead of using two large pads, multiple (more than two) smaller sized gel electrodes are used to target specific cortical structures. This new approach is called High Definition tDCS (HD-tDCS).

There are three different types of stimulation: anodal, cathodal, and sham. The anodal stimulation is positive (V+) stimulation that increases the neuronal excitability of the area being stimulated. Cathodal (V-) stimulation decreases the neuronal excitability of the area being stimulated. Cathodal stimulation can treat psychological disorders that are caused by the hyper-activity of an area of the brain. Sham stimulation is used as a control in experiments. Sham 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. By comparing the results in subjects exposed to sham stimulation with the results of subjects exposed to anodal or cathodal stimulation, researchers can see how much of an effect is caused by the current stimulation, rather than by the placebo effect.

Transcranial direct current stimulation in the current period is beginning to be used more frequently as a brain stimulation technique because is considering as a safe method for human use.

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