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COST EFFECTIVE TRANSCRANIAL DIRECT CURRENT STIMULATION DEVICE FOR THE TREATMENT OF DIFFERENT NEUROLOGICAL DISORDERS

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ABSTRACT
Transcranial direct current stimulation (tDCs) is a non-invasive brain stimulation technique that involves applying a milliampere electrical current to the scalp to change cortical excitability and activity. Psychological states known as neuropsychiatric disorders which include substance abuse, depressive disorders, and schizophrenia, are marked by abnormal affective and psychological functioning. These illnesses have a significant impact on an individual's social life and functioning. For thousands of years, people have used electricity, especially from electric fish, to treat pain as well as other diseases. For neuromodulation several noninvasive methods have also been used like Transcranial electrical stimulation (TES), Electroconvulsive therapy (ECT), Transcranial alternating current stimulation (tACs), Deep brain stimulation (DBS) etc. Above mention devices are working on AC current which is not safe for human beings but tDCs device work on DC current which is safe for human beings. The objective is to design a low cost tDCs device and increase the range of current upto 4 milliampere as well as to increase the time duration of session upto 40 minutes. The working of tDCs prototype depends on a microcontroller-based embedded system and a current circuit which is used to provide the milliampere current to the patient. The programmed microcontroller is used to control the current and the sponge electrodes are placed on the head of the patients through these electrodes the current is delivered. Transcranial direct current stimulation device work on four different conditions and test the device on simulator to get the desired results. The most common problem in Pakistan is neurological and mental disorders their treatment options are less and expensive. The prototype designed is maybe a life supporting device that addresses these issues related to mental and neurological disorders. The future work is to perform clinical trials on tDCs devices and enhance its efficiency and safety.

INTRODUCTION
Transcranial direct current stimulation (tDCs) is a non-invasive brain stimulation technique that involves applying a milliampere electrical current to the scalp to change cortical excitability and activity. Psychological states known as neuropsychiatric disorders, which include substance abuse, depressive disorders, and schizophrenia, are marked by abnormal affective and psychological functioning. These illnesses have a significant impact on an individual's social life and functioning. [1]. Together, these diseases constitute the largest cause of the global burden of non-fatal diseases accounting for approximately 80% in 2016 and this range is expected to expand

further in the future. Additionally, many patients with MDDS do not respond to standard treatment with pharmacotherapy and/or psychotherapy. Treatment options for people who have mental disorders including neurological and neuropsychiatric disorders are limited, costly, and time taking[2]. A promising neuromodulation approach that could be used in this scenario is tDCs. Apart from psychotherapy, which triggers seizures with a quick, intense stimulation, tDCs involves the administration of low-intensity electrical currents for a specific period usually 10-30 minutes using an electrode positioned on the scalp. There are no seizures produced and therefore no general anesthesia or intensive monitoring is required. In addition transcranial direct current stimulation tDCs which is thought to be able to normalize brain abnormalities in neuropsychiatric patients has been rigorously studied recently for its effects its suggested[3]. Enhancing Human cognitive functions have long been the subject of research exploration as well as tDCs has recently gained popularity emerged as a promising tool for enhancing human brain ability and motor skills[4]. International neurological ailment is the second most common reason for dying or impairment about 60-80 percent neurological disorder have already been recorded, specifically in the developing countries because of poverty, malnutrition, loss of assets, and overpopulation resulting a critical and problematic circumstance. Neurological disorders that are most common in developing nations include drug addiction, tinnitus, migraine, epilepsy, and stroke. The rehabilitation of individuals with neurological illnesses has steadily incorporated noninvasive brain simulation (NIBS) over the past 20 years. In terms of widespread improvement in a variety of neurological illnesses, it is one of the safest and most effective procedures[5]. The use of transcranial direct current stimulation (tDCs) as a method to modify cognitive function has gained attention. Transcranial direct current stimulation is a famous mind enhancement approach which is used to enhance brain activity. It is a valuable device for the treatment of neuropsychiatric conditions which includes depression, anxiety as well as cognitive, speech, and motor symptoms associated with illnesses like multiple sclerosis[6]. Major depressive disorder, Alzheimer's disease, Stroke, Parkinson's disease, and other movement disorders are examples of neurological diseases[7]. The health risks of tDCs are still under investigation, but the side effects seen so far are minor and related to the electrodes[8]. This is associated with temporary dryness, itching, and tingling additional health concerns connected to tDCs may include headache and drowsiness all of these side effects are last within 10 to 15 minutes. Placement of the electrodes too close to the eyes may result in additional adverse effects, such as transient, non-hazardous flash phosphine[9]. However, it is important to keep in mind that tDCs safety and tolerability data are derived from controlled human trials conducted with specialized equipment and strictly controlled protocols such as limiting the current duration or the number of sessions[10].

For thousands of years, people have used electricity, especially from electric fish, to treat pain as well as other diseases. Transcranial electrical stimulation (TES) devices for brain stimulation became available to the general population at the end of the 1700s. In the 1800s and early 1900s in the United Kingdom, these machines employed a battery, friction, or static to generate a moderate electrical current[11]. The simple procedure could be self-administered, and physicians' therapists and patients all said it could induce sensations of euphoria and increase mental performance but because of the lack of regulation around its use it's believed to have caused adverse effects like nausea, vertigo, and headaches. For neuromodulation several other noninvasive methods have also been used, ECT (electroconvulsive therapy) was first performed on a human subject in 1938 by neurologist Ugo Cerletti[12]. In order to produce a seizure in a schizophrenia patient, Ugo Cerletti utilized a series of electrical shocks. This allowed the patient's hallucinations and confusion to end and helped them get back to their normal state of mind. Within a few years of its creation ECT was being used extensively in mental hospitals all over the world[13].However, throughout the twentieth century, it was frequently used to manage severe condition of patients as well as to improve their mental health. In ECT general anesthesia is given to the patient then current is delivered to the patients[14]. The use of ECT decreased in the

1960s and 1970s despite increasing proof that it might be beneficial in treating mental health issues. Because ECT has severe and long term side effects such as Apathy (lack of interest in things), Loss of creativity, ambitions, energy, Difficulty in focusing, Loss of emotional response[15]. Transcranial alternating current stimulation (tACs) device delivers a low-intensity sinusoidal electrical current to the brain using electrodes on the scalp. The method is to believe to increase the brain's own oscillations, which can be used to treat disease or improve brain function and can be painless[16]. Deep brain stimulation (DBS) involves implanting electrodes into the brain tissues. These electrodes generate electrical pulses to correct abnormal impulses. A pacemaker-like device placed beneath the skin to regulates the intensity of stimulation in deep brain stimulation. in your upper chest typically right below the collarbone, however occasionally in the chest or belly[17] DBS device links to electrodes in your brain by running under your skin. Above mention devices are working on AC current and implanting electrodes which is not safe for human beings but tDCs device work on DC current which is safe for human beings. The objective is to design a low cost tDCs device and increase the range of current upto 4 milliampere as well as to increase the time duration of session upto 40 minutes.

METHODOLOGY

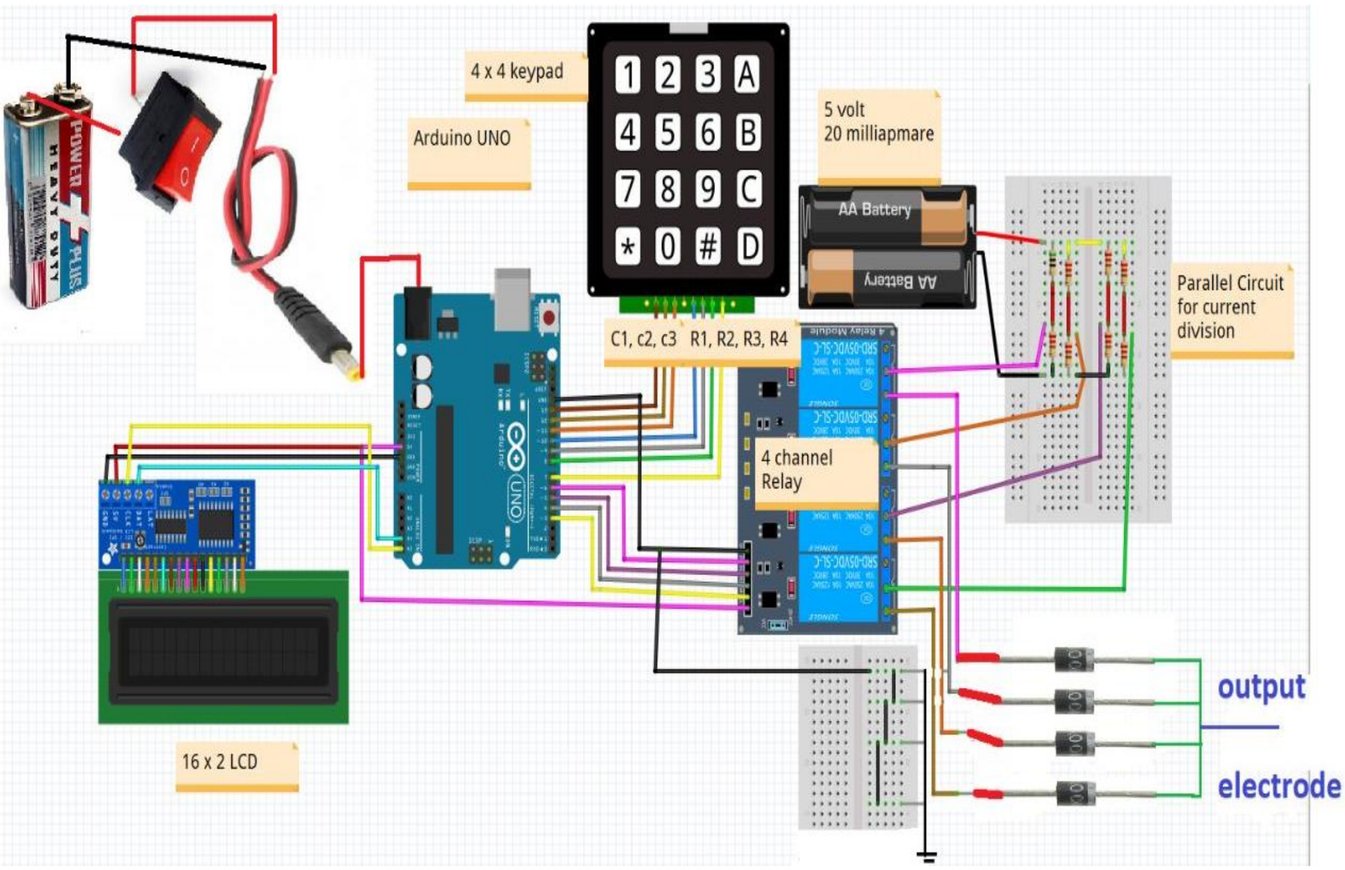

Figure 01: The proposed method for the working of Transcranial direct current stimulation (tDCs) prototype based on a microcontroller (Arduino Uno) connected with the LCD, Keypad, 4channel relay, 12-volt battery and a Current circuit**.**

The working of tDCs prototype depends on a microcontroller-based embedded system and a current circuit as shown in Figure 01 which is used to provide the milliampere current to the patient. The research based on hardware and software, the software that used in this research is Arduino IDE for programming Microcontroller[18] which has been used as a central processing and controlling unit for the accomplishment of given commands to the circuitry. The hardware components are Arduino Uno (ATmega328p) microcontroller [19] which is used to controls overall operations, current circuit control or maintain the voltage and current at a specific range, resistors are used to divide the current equally in the electrodes, 4 channel relay module used as a switch and sponge electrodes deliver the current to the specific part of the brain. The targeted areas for the electrode placement must be identified further information on localization techniques is provided in the section Localizing Electrode Placement. Before putting the electrodes in place the researcher should examine the scalp for any wounds or injuries[20]. When using saline as a conductor the electrodes can be placed in sponge-holding bags filled with saline just make sure the bags are sufficiently damp but not pouring. To guarantee proper contact between the electrode and the patient's scalp, the hair should be separated[21]. To ensure excellent contact between the electrode and the patient's scalp split the patient's hair saline should not be applied to the hair. Electrodes are then linked to the stimulator through cables connected to anodal/cathodal ports. After positioning the electrode over the target area it should be secured with a cap, rubber bands or an elastic tubular net. After that the reference electrode should be fixed in the same way. After attaching the electrodes, the stimulation duration, current intensity, and ramp-up/ramp-down times must be configured. To keep conductivity flowing through the circuit, tDCs application needs to be reliable and consistent and must make adequate contact with the scalp[22]. The device use milliampere current ranges from 1 milliampere to 4 milliampere and the duration of session must be between 10 to 40 minutes. The power supply is connected to the electrodes, the positive anode and the negative cathode, electrode placement depends on the patient condition so according to condition of patient cathode and anode electrodes are placed to specific part of the brain to deliver current.

The block diagram of tDCs device as shown in Figure 02 work on four conditions: 1st Condition 1mA current is deliver to the patient for 10 minutes. If patient need more stimulation, then session will be doubled. 2nd Condition 2mA current is deliver to the patient for 20 minutes. If patient need more stimulation, then session will be doubled but firstly the doctor must check the condition of patient whether there is a need of extra session or not. 3rd Condition 3mA current is deliver to the patient for 30 minutes. 4th Condition 4mA current is deliver to the patient for 40 minutes according to patient condition.

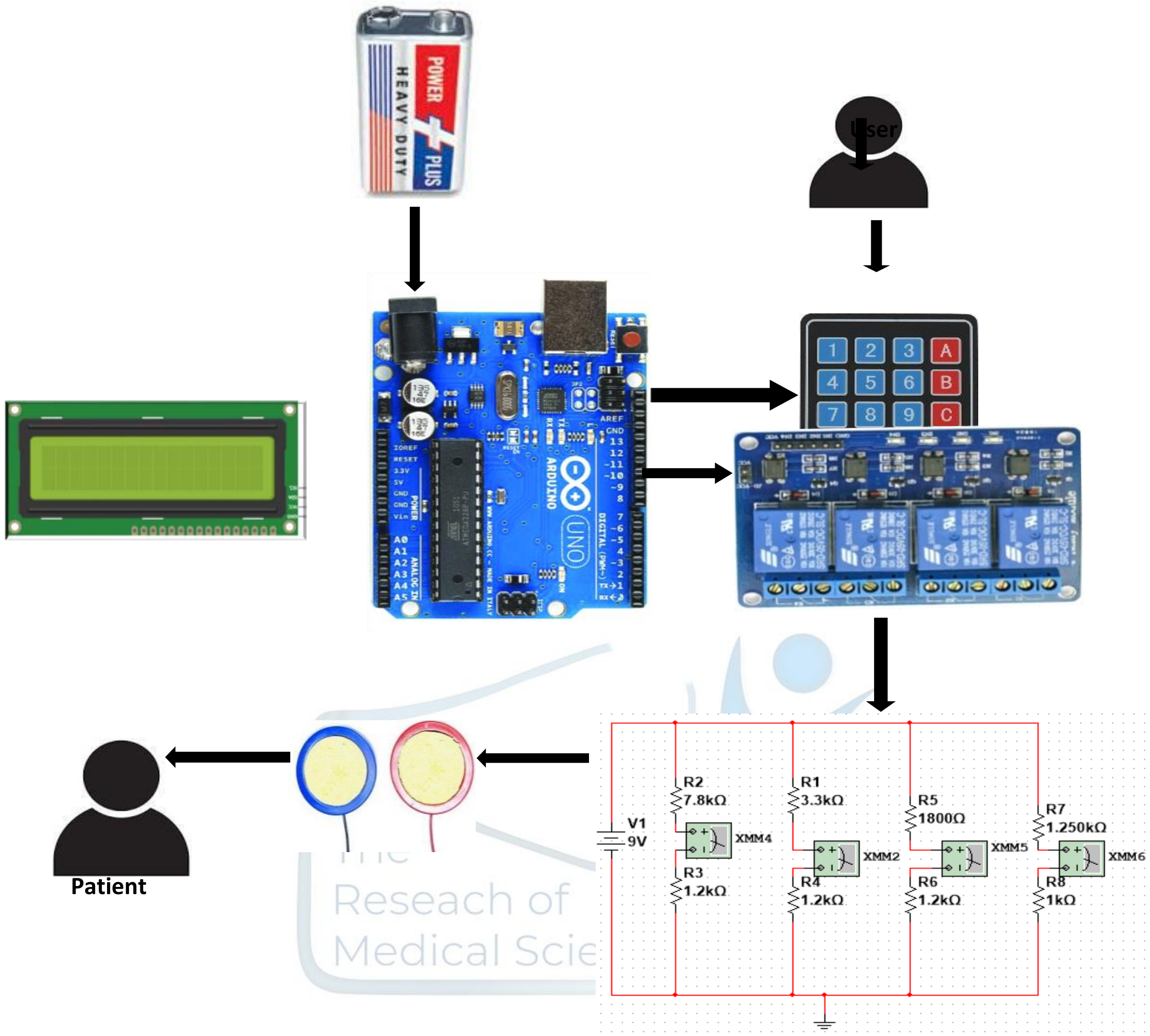

Figure 02: Block diagram of tDCs device in which microcontroller-based embedded system and a current circuit which is used to provide the milliampere current to the patient through electrodes, which are placed on particular regions of the scalp. The positive electrode, known as the anode, is positioned over the part of the brain that needs stimulation. The negative electrode, or cathode, is positioned over a portion of the brain that is not being stimulated.

RESULTS AND DISCUSSION

In the research study as graph shown in Figure04 and table 01 it shows the meta-analysis of various patients having different health conditions. The stroke patient comes with a severe condition and need a high stimulation procedure so healthcare professional give 4 milliampere current intensity and set the time duration 40 minutes and check the condition after first session. Additionally, in psychiatric patients who have moderate condition the practitioner give 3 milliampere and set duration for 30 minutes. Onwards in epilepsy patient having mild symptoms practitioner give 2 milliampere for 20 minutes and for other disorders 1 milliampere current is delivered for 10 minutes

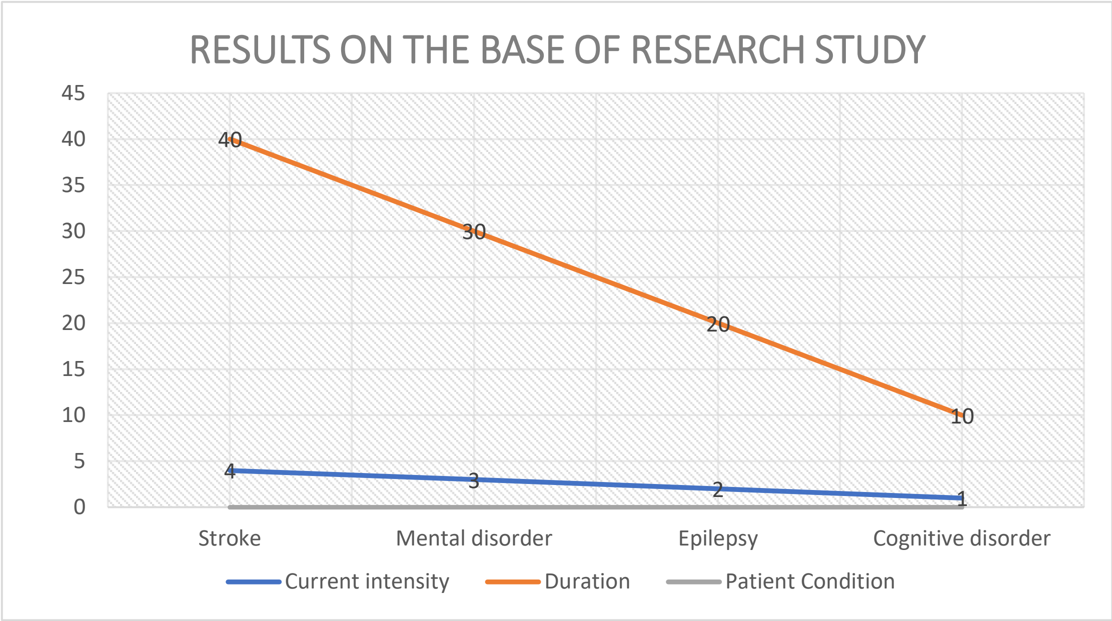

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Figure 03: Graph of meta-analysis of patients having tDCs session

Disorders	Current intensity	Session duration	Condition
Stroke	4 milliampere	40 mints	Severe
Mental disorder	3 milliampere	30 mints	Moderate
Epilepsy	2 milliampere	20 mints	Mild
Cognitive disorder	1 milliampere	10 mints	Low

Table 01: Analysis of tDCs session on different conditions

The designed tDCs prototype as shown in Figure04 and incorporates a microcontroller-based embedded system and a current circuit. The amount of current which is delivered to the patient and the time duration are displayed on an LCD.

Transcranial direct current stimulation device work on four different conditions test the device on simulator to get the desired results as shown in Figure 05, 06, 07, 08.

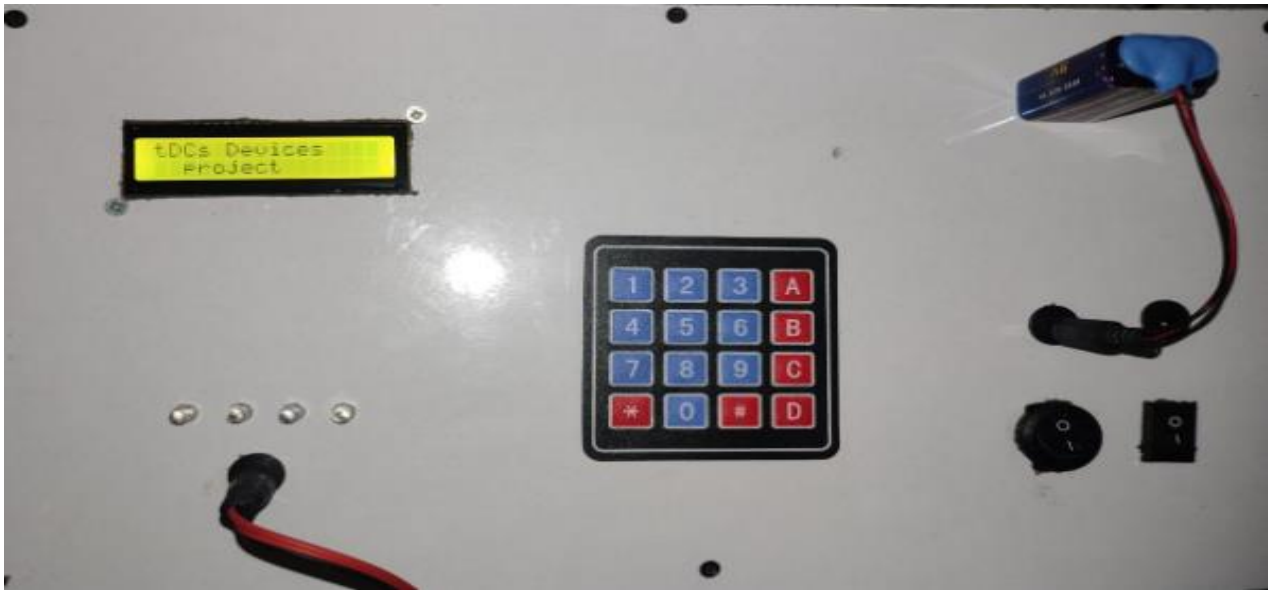

Figure 04: The designed prototype of low cost tDCs device for non-invasive brain stimulation.

Figure 05: The result achieved at 1st condition in which 1mA current is delivered to the patient for 10mints.

Figure 06: The result achieved at 2nd condition in which 2mA current is delivered to the patient for 20mints.

Figure 07: The result achieved at 3rd condition in which 3mA current is delivered to the patient for 30mints.

Figure 08: The result achieved at 4th condition in which 4mA current is delivered to the patient for 40mints.

CONCLUSION AND FUTURE WORK

The most common problem in Pakistan is neurological and mental disorders their treatment options are less and expensive. The prototype designed maybe a life supporting device that addresses these issues related to mental and neurological disorders. This prototype will deliver a small amount of current in milliamps according to specific time duration. Both these parameters are set according to patient condition. Furthermore, this prototype is noninvasive brain stimulation device to modify the activity of particular brain regions for a number of conditions, including depression, parkinson's disease, chronic pain, and cognitive improvement. When applied correctly tDCs is generally regarded as safe, and its side effects, which often include tingling or itching, are typically minor and it last within 5 to 10 minutes. The future recommendation is to perform clinical trials on tDCs device to enhance its efficiency and safety.

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