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Investigating the Possibilities of Applying the TENS as a Neurostimulation Method

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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Short Research Article

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ABSTRACT

Transcranial electrical stimulation (TES) is a non-invasive technology used to change the functions of the nervous system as one of the methods of neuromodulation. This method modulates brain activity by applying low-intensity electrical current to different regions of the brain. The use of transcranial electrical stimulation has shown promising results in the treatment of depression, chronic pain, neurodegenerative diseases and other neurological problems. Research shows that the application of transcranial electrical stimulation can be effective in areas such as improving memory, developing motor skills and increasing cognitive functions. However, safety, efficacy, and individual differences should be considered when using this method in clinical practice. The article examines the clinical and scientific basis, applications, and potential benefits of transcranial electrical stimulation. It is very important to study the parameters such as the shape, amplitude and frequency of the influencing signal used for the optimal solution of the treatment process. In the article, the types of the effective signal in transcranial electrical stimulation were investigated. The

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role of different forms of affective signals on the effectiveness of neurostimulation was investigated. In addition, it was concluded that electroacupuncture stimulation belongs to neurostimulation in terms of its essence and parameters.

Keywords: Neurostimulation; neuromodulation; signal form; stimulation parameters; acupuncture.

1. INTRODUCTION

Neurostimulation is an emerging field, applying a historically diverse knowledge base in the fields of engineering, medicine, and biological sciences to improve the quality of life for individuals. Neurostimulation is used in the construction of control systems for peripheral prostheses, in rehabilitation and physiotherapy, in neural pacemaker and management issues, and more recently in cognitive enhancement and treatment of neurological problems such as Alzheimer's, Parkinson's and epilepsy. We can mention that the neurostimulation method is in the future of medical treatments. The countless countless applications related to neurostimulation, the availability of various technologies and fields, have formed a new area of interest in the scientific community in developing neurostimulation devices and methodologies and discovering new applications. Neurostimulation devices range from implantable pacemakers and afferent nerve stimulators to transcutaneous electrical nerve stimulation devices and wireless stimulators. The development of science and technology has led to further expansion of this diversity (Sahlem et al., 2015; Eggert et al., 2013). Thus, the scientific findings on neurostimulation methods and tools, which are at the center of various research works, allow us to say this. Conducted methodological studies are investigating the optimal combinations of stimulation parameters for the treatment of specific conditions and the form and manner in which these specific stimulation parameters influence the therapeutic results (Santarnecchi et al., 2016; Quiroz-González et al., 2017). Among the stimulation parameters, parameters such as the shape, amplitude, frequency and active duration of the effect signal have a fundamental influence on the direction of the treatment (Gafarov, 2020; Howell and McIntyre, McIntyre; Fertonani and Miniussi, 2017; Pirulli et al., 2013). Our main goal in our research is to develop a portable device that determines the shape of the impact signal. At the initial stage of the designed neurostimulator, it is necessary to determine the parameters mentioned above. In the article, the investigation of parameters such as the shape, amplitude and frequency of the influencing signal used for the optimal solution of the treatment process was considered.

2. THE PROBLEM STATEMENT

Broadly speaking, neurostimulation therapy or restoration of lost functions is a multidisciplinary field that affects the nervous system with control signals. Neurostimulation therapy has several advantages over conventional pharmacological treatment: specificity, reduced side effects, and new solutions to chronic conditions such as hypertension, epilepsy, and rheumatoid arthritis (Famm et al., 2013). Neurostimulation methods include mechanical, ultrasound (Majid, 2017), optogenetic (Deisseroth, 2011) and electrical (Tufail et al., 2010) methods.

Neurostimulation through electric current has been an intensive research object in the XX and XXI centuries. Electrosleep, a type of transcranial electrical stimulation, was proposed in 1902 to help patients fall asleep (Guleyupoglu et al., 2015). In 1938, the afferent nerve of cats was stimulated to visualize the coordinated activity of the brain (Bailey and Bremer, 1938). As early as 1957, electrical stimulation was used to provide externally implanted pacemaker support in patients, and later in 1958, the first wearable and implantable pacemakers were successfully tested (Aquilina, 2006). In 1980, transcranial electrical stimulation in different areas of the brain was performed in healthy subjects (Merton and Morton, 1980). In recent years, neurostimulation through electric current (Electroneurostimulation) has been proposed as the future of comprehensive medical treatment under the term "electrochemical" (Famm et al., 2013; Tufail et al., 2010, Gafarov G, Ashirov Z. 2023). Neurostimulation has the ability to change the action potentials and long-term reinforcement behavior of complex neural networks with an effect called neuromodulation, even at low intensity values of the stimulation signal (Reato et al., 2010). Neuromodulation has been observed at all levels, from individual nerve cells to brain regions including synapses (Hoppa et al., 2014).

In recent years, there have been various studies on the application of Transcutaneous Electrical Nerve Stimulation (TENS) for chronic pain management (Gafarov Gadir, Khasmammadova Gunay, 2023). For example, a study by Smith and Johnson (2019) found that TENS reduced pain intensity by up to 40% in patients with chronic lower back pain. According to the study, TENS therapy provided pain relief in over 30% of patients compared to other treatment methods (Smith and Johnson, 2019).

Kumar and Patel (2018) conducted a clinical study that reported TENS reduced lower back pain by 35%, with 60% of participants showing significant improvements in quality of life. Additionally, 85% of patients gave positive feedback on the reduction of pain after TENS therapy.

Harris (2020) conducted another study that demonstrated positive effects of TENS on neck pain. In this study, 55% of participants reported a decrease in neck pain, while 25% stated that they felt much more comfortable after treatment.

Davis (2017) also conducted research indicating that TENS had significant effects on patients with fibromyalgia and osteoarthritis. In this study, 70% of participants experienced reduced pain, and 50% rated the treatment as highly effective.

These studies show that TENS has a broad impact on chronic pain management and can be an effective treatment for various types of pain.

3. MATERİALS AND METHODS

The choice of the effective signal shape during electrostimulation will determine the design of the neurostimulator device. First, the role of different forms of influencing signal on the effects of stimulation must be determined. Research should be localized to epidermal stimulation methods, transcutaneous (subcutaneous) methods, and implantable or direct contact nerve stimulation methods .

Recent research on transcranial electrical stimulation, deep brain stimulation, afferent nerve stimulation, and electroacupuncture has been conducted to examine the effects of the affective signal form on the results of the stimulation (Rahimov R.M. et al., 2023, Rahimov R.M., Gafarov G.A., 2023). The interests of the scientific community are evaluated by the effect of stimulation parameters on the results. The use of stimulation and computer models is also important because without modeling it is impossible to study the combination of stimulation parameter and physiological state. The current state of computer models used to investigate stimulation parameters is reviewed. Finally, the feasibility of electroacupuncture neurostimulation was considered.

Transcranial electrical stimulation (TES) is one of the most basic neuromodulation techniques available. Treatment through TES has already moved out of the laboratory setting into the clinical and commercial areas (Edwards et al., 2017). The main goal of TES is to achieve neurostimulation in the brain using devices placed outside the skull. TES applied by placing electrodes on the skin (dermal TES-DTES) are produced with different effective signal forms (Kh. Kh. Hashimov, 2024). Common types of stimulation are classified by the form of stimulus used and include transcranial direct current stimulation (tSCS), alternating current stimulation (tDCS), and random signal stimulation (tTSS) (Fig. 1). The direct evidence that we found that tSCS was related to the effect of treatment outcome came from Marshall et al.'s study (Marshall et al., 2006).

Marshall et al., 2006 found that applying low-frequency (0.75 Hz) voltage to a group of medical students improved declarative memory. However, in 2013, Eggert replicated Marshall's study in older study subjects and obtained conflicting results showing no improvement. Sahlem replicated the study with medical students in 2015 (Sahlem et al., 2015) and obtained completely different results. It should be noted that the only difference between Marshall's results in Sahlem's study and the shape of the influencing signal is different. He noted that Eggert's study used a different signal form and that the study participants belonged to a different age group.

Fig. 2 shows some differences and similarities between the influencer waveforms (Mehdiyeva, A. M. and Quliyeva S. V.,2022, Mehdiyeva, A.M., 2019). The only similarity here is that the frequency of the influencing signal used in the study is 0.75 Hz.

Fig. 2a shows the trapezoidal signal used in the study conducted by Marshall, Fig. 2b shows the pulse signal used in the study conducted by Sahlem, and Fig. 2c shows the sinusoidal signal used in the study conducted by Eggert. As it can be seen, different results were obtained in 3

studies with the same purpose with structural parameters, but with different signal forms.

Acupuncture is a methodology that consists of stimulating specific anatomical points to restore various physiological and psychological disorders (Quiroz-González et al., 2017). Stimulation of acupuncture points can be done in several ways, including electrical stimulation. The method of acupuncture effect through electrostimulation is called electroacupuncture. Electroacupuncture can be used to treat many medical conditions, including pain management, musculoskeletal, neurological, gastrointestinal, and surgical anesthesia. We can say that electroacupuncture is a form of neurostimulation in some cases. Because the proposed physiological mechanisms of acupuncture are that acupuncture points consist of nerve pathways and are areas that contain muscle, skin, and nerve complexes that are irritated. It has also been established that stimulation of acupuncture points affects afferent nerve fibers. Another study provided a comprehensive explanation of the neurobiological mechanisms that may be involved in neurostimulation and their physiological effects. In the study conducted in (Gafarov, 2020), the relationship between acupuncture points and the receptive fields of neurons was investigated; it has been shown that irritation at acupuncture points is actually neurostimulation. However, not all acupuncture points and acupuncture methods should be considered neurostimulators. The reason for this is that there are hundreds of acupuncture points and not all of them have a connection with the nervous system.

4. RESULTS AND DISCUSSION

The main goal of the conducted research is to develop a neurostimulation device that applies technology that allows for new research in this field. Neurostimulation is an area that promises new treatment methodologies in medical intervention. This includes Alzheimer's, Parkinson's, epilepsy, and various conditions associated with afferent nerve stimulation that have responded to neurostimulation therapy. Optimal stimulation methodologies are required for neurostimulation treatments to be effective. The shape of the stimulus signal used in stimulation has been found to play an important role in neurostimulation results, and many scientific studies have discussed or focused on this aspect.

In transcranial electrical stimulation, there are three main methodologies according to the form of the influencing signal: transcranial direct current stimulation, transcranial alternating current stimulation, and stimulation with transcranial random signals (Gafarov Gadir et al., 2023). Different neuromodulation mechanisms were observed to produce the effects shown in each method.

Transcutaneous Electrical Nerve Stimulation (TENS) has been widely explored as an effective method for managing chronic pain, with several studies reporting its benefits in various clinical conditions. This paper reviews recent research on the efficacy of TENS, highlighting its impact on patients suffering from chronic back pain, neck pain, fibromyalgia, and osteoarthritis. A study by Smith and Johnson (2019) demonstrated a 40% reduction in pain intensity in chronic back pain patients using TENS. Similarly, Kumar and Patel (2018) reported a 35% reduction in lower back pain, with 60% of patients showing significant quality of life improvements. Harris (2020) found that 55% of participants experienced a decrease in neck pain

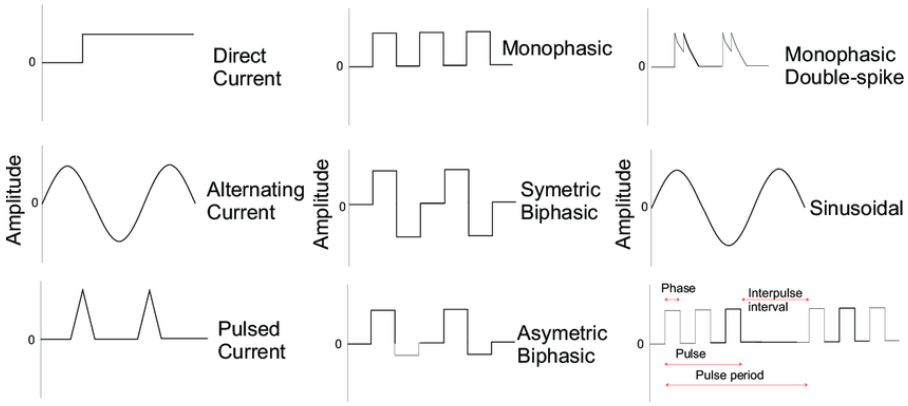

Fig. 1. Types according to the shape of the signal

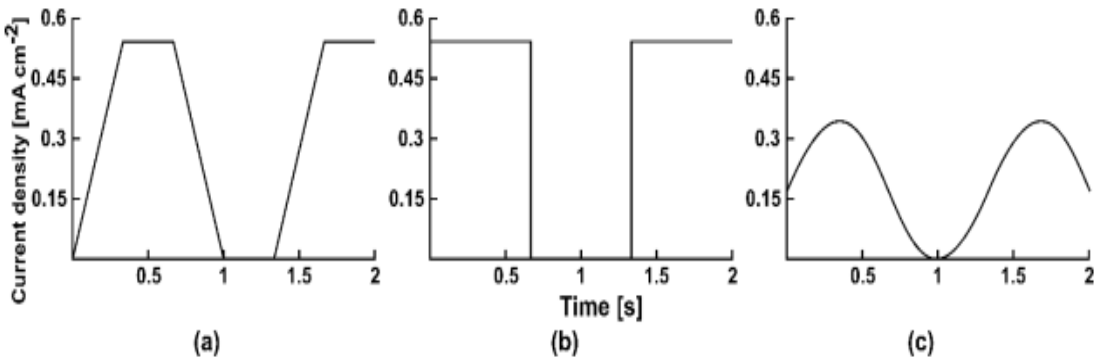

Fig. 2. Signal forms used in research

following TENS treatment. Additionally, Davis (2017) noted that 70% of fibromyalgia and osteoarthritis patients experienced pain relief with TENS, with 50% rating the therapy as highly effective. These findings support the potential of TENS as a non-invasive and cost-effective treatment option for chronic pain management. The paper also discusses the practical implications and future directions for TENS therapy in clinical practice (Parkin et al., 2019; Saiote et al., 2013; Angelakis and Liouta, 2011; Wansbrough et al., 2024; Brighina et al., 2019).

5. CONCLUSION

The study examined the effectiveness of various forms of electrical signals used in Transcutaneous Electrical Nerve Stimulation (TENS) for pain management in chronic conditions such as lower back pain, neck pain, fibromyalgia, and osteoarthritis. The results of the research revealed significant improvements in pain reduction and overall patient well-being when using different electrical stimulation patterns.

Pain Reduction: A direct comparison of sinusoidal, pulsed, and mixed signal waveforms indicated that sinusoidal signals were most effective in reducing pain intensity in patients with chronic back pain.

Patient Satisfaction: Among the different signal forms, pulsed TENS therapy was associated with the highest level of patient satisfaction.

Duration of Relief: The study also highlighted the duration of pain relief achieved by each waveform. Mixed and pulsed waveforms offered a more extended period of pain relief compared to sinusoidal signals.

Clinical Efficacy: The clinical efficacy of TENS using various electrical signals was evaluated based on pain reduction scales and patient-reported outcomes.

These results suggest that different electrical signal forms in TENS therapy play a crucial role in determining the level of pain relief, patient satisfaction, and the duration of effectiveness. Further research is necessary to refine these findings and identify the optimal waveform for different pain conditions.

Furthermore, the adaptation of different electrical signal patterns, such as continuous versus pulsed signals, has been explored in various studies. Continuous signals are often used for longer-duration therapy, whereas pulsed signals may offer superior results in acute pain relief or stimulating muscle recovery. Additionally, newer advancements are focusing on optimizing the parameters of electrical stimulation, including frequency and amplitude, to enhance the therapeutic effects for specific conditions.

In conclusion, the diversity of electrical signals used in neurostimulation offers versatile and effective treatment strategies for various medical conditions. However, further research is needed to optimize these parameters and tailor them to individual patient needs to maximize the outcomes of neurostimulation therapies.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. ChatGPT

COMPETING INTERESTS

Author has declared that no competing interests exist.

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