



Cognitive Improvement Through Non-Invasive Brain Stimulation Techniques in Healthy Adults

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Article Information:

Received Oct 03, 2024

Revised Oct 31, 2024

Accepted Dec 01, 2024

ABSTRACT

Cognitive enhancement is an effort to improve or improve mental functions such as memory, attention, problem solving, language, and other thinking skills. In healthy adults, the goal of cognitive enhancement is to improve current mental abilities, increase productivity, and prolong periods of mental clarity. This research was conducted with the aim of exploring various non-invasive brain stimulation techniques such as tDCS, TMS, and tACS, which offer innovative ways to improve various aspects of cognitive function without the need for invasive procedures. While there are many potential benefits, it is important to understand the long-term effects, optimize use methods, and ensure use of this technology is safe and ethical. The method used by researchers in researching Cognitive Improvement Through Non-Invasive Brain Stimulation Techniques in Healthy Adults is to use a quantitative method. The data obtained by researchers was obtained from the results of distributing questionnaires. The distribution of questionnaires carried out by researchers was carried out online using Google Form software. The results of data acquisition will also be tested again using the SPSS application. From the research results, it can be seen that this research is an interesting and continuously developing field in neuroscience and psychology today. With non-invasive brain stimulation techniques, it is possible to stimulate certain areas of the brain, thereby further improving cognitive functions such as memory, attention and problem solving in healthy adults. From this study, researchers can conclude that non-invasive brain stimulation, such as repetitive transcranial magnetic stimulation (rTMS) and transcranial direct current stimulation (tDCS), has been proven to improve motor and cognitive function in healthy adults. Recent research shows that tDCS can modulate the brain's motor cortex, which functions to increase intelligence in healthy adults.

Keywords: Adults, Cognitive, Stimulation

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How to cite:

Kurniawan, W., Jixiong, C., Abdullah, A., Wei, Z & Sari, F. (2024). Cognitive Improvement Through Non-Invasive Brain Stimulation Techniques in Healthy Adults. *World Psychology*, 3(3), 335-453. <https://doi.org/10.55849/wp.v3i3.712>

Published by:

Sekolah Tinggi Agama Islam Al-Hikmah Pariangan Batusangkar

INTRODUCTION

An adult is usually defined as someone who has reached the age of majority, which usually starts at the age of 18 or 21, depending on the cultural and legal context (Plym et al., 2023). Adults have full responsibility for their lives, including social, economic responsibilities, and so on (Sharma et al., 2021). In general health, a healthy adult is defined as an adult individual who is not only free from disease but is also in good physical, mental, and social condition (Holscher et al., 2018). Meanwhile, adults who are psychologically healthy means being able to maintain their emotional balance by working productively and contributing to their community (Natarajan et al., 2021). Healthy adults also have a positive perspective on themselves and life, and are healthy and able to achieve their potential as a maturity in self-fulfillment.

Cognitive enhancement in healthy adults refers to the process and outcome by which cognitive abilities such as memory, attention, problem solving, and reasoning can develop or remain robust with age (Rose et al., 2021). Cognition is all mental activity that makes healthy adults able to relate, assess, and consider events so as to gain knowledge afterwards (Bae & Kang, 2022). In addition to cognitive improvements, emotional intelligence, the ability to understand and control emotions, and better social relationships are all demonstrated by adults (Hirsch et al., 2021). Although there is a natural tendency to decline in some cognitive aspects with age, healthy adults often show improvement or stability in certain cognitive aspects (Serio et al., 2022). Activities that challenge the brain can encourage the formation of new neural connections and improve cognitive function, as the adult brain can still adapt and change in response to experience and learning (Trebeau Crogman & Crogman, 2020).

There are many ways and activities that healthy adults can engage in to maintain or improve cognitive function as they age, known as cognitive enhancement (Lamaziere et al., 2020). To prevent cognitive decline, it is important to have regular health check-ups and manage chronic medical conditions such as hypertension, diabetes, and high cholesterol (Jayaram et al., 2019). For healthy adults, cognitive improvement requires a broad approach that includes comprehensive management of stress and health conditions, a physically and mentally active lifestyle, and good nutrition (Griffen et al., 2022). Other methods and activities that healthy adults can do to maintain cognitive improvement, one of which is getting enough sleep. By maintaining sufficient quality sleep, the brain will work and cleanse toxins, so it will be faster in processing new information (Schladitz et al., 2022).

Brain development in healthy adults continues, although not as fast as in children. Some important aspects of adult brain development include neuroplasticity. In neuroplasticity, the brain of healthy adults can always adapt, learn new things, and

repair itself after injury (Jung et al., 2020). Healthy people's neural connections can be improved through mental activities such as playing music or learning a new language. Furthermore, the growth of new nerve cells (neurogenesis) will occur in several parts of the brain (Kuhn et al., 2018). Due to the growth of new nerve cells that continue to develop in healthy adults, such as the hippocampus, which plays a role in memory and learning (Moxon et al., 2019).

Brain stimulation is a popular treatment method for mental disorders and other brain-related disorders (Fond et al., 2021). This therapy appeals to those who have not tried other treatment methods or want an effective solution with few side effects (Brookman-Frazee et al., 2018). Neurostimulation is the official term for brain stimulation. In simple terms, this is a deliberate enhancement of the nervous system. This can be achieved through invasive techniques such as microelectrodes or non-invasive techniques such as transcranial magnetic stimulation or transcranial electrical stimulation (Iorfino et al., 2019). A series of methods known as non-invasive brain stimulation have the ability to change brain function without disturbing its surface. This technique is considered safe because it does not involve the introduction of instruments in the head (Vigo et al., 2019).

Brain stimulation can control brain behavior in healthy adults. In this case it consists of two main categories, namely invasive and non-invasive (Vignaud et al., 2018). Deep brain stimulation is part of the invasive techniques. Non-invasive electrical stimulation uses tDCS, transcranial stimulation, etc., and these methods activate neurons in the brain (Liebrand et al., 2020). Think of NIBS like an alarm that helps someone wake up. This joy can improve the symptoms of certain mental illnesses. The main basis is the application of electricity to excite neurons. Because they are safe and effective, non-invasive techniques are becoming more popular today. A non-invasive brain stimulation method is transcranial magnetic stimulation (TMS). TMS is very effective because it can target cortical areas precisely. This method also changes the rhythm control system (Breitling et al., 2020). This method uses short signal patterns to activate neurons in specific areas.

Non-invasive brain stimulation for cognitive enhancement in healthy adults can increase the ability to maintain maximum memory (Muhammad & Anwary, 2019). With rTMS and tDCS sessions one has even shown improvements in brain function tested in healthy adults showing improved memory. The patient's working memory became better even after a week of stimulation (Neri et al., 2020). Furthermore, anodal TDCS can also improve the ability of healthy adults to learn certain sequences or events when attached to the side of the forehead opposite to the working hand, and the ability to complete complex motor tasks is also improved (Gilam et al., 2018). The existence of non-invasive brain stimulation techniques can also help healthy adults focus their attention on certain stimuli.

The type of method used in this research is a quantitative method. This method is used so that the final results of the processed data can be known clearly and precisely regarding Cognitive Improvement Through Non-Invasive Brain Stimulation Techniques

in Healthy Adults (Lopez & Adair, 2019). The data collection process was obtained by the researcher from the results of the respondents' answers that the researcher had carried out. Researchers created a questionnaire with 10 questions, then distributed it via Goggle from. After the data is collected, the data will be calculated into a percentage and presented in table form (Fritz, 2020). In processing research data, researchers use SPSS software which aims to make it easier for researchers to process data, and the data results are more relevant (Henley et al., 2020). Furthermore, the researcher really hopes that the next researchers will research and study more deeply regarding Cognitive Improvement through Non-Invasive Brain Stimulation Techniques in Healthy Adults.

RESEARCH METHOD

Research Design

In examining research on Cognitive Improvement Through Non-Invasive Brain Stimulation Techniques in Healthy Adults, using quantitative methods. The aim of using quantitative methods is to collect research data and test the hypotheses that have been formulated (Noll & Tackett, 2023). Then the researchers created a questionnaire created in the Google Form application which was distributed online to respondents via the WhatsApp application. The questionnaire contained 20 questions asked by the researcher. To fill out the questionnaire, the researcher has provided four options, namely strongly agree, agree, disagree and disagree. So respondents can respond to the questions asked by the researcher by selecting these four options

Research Procedure

In this study, researchers investigated cognitive improvement through non-invasive brain stimulation techniques in healthy adults. The aim of the researcher is to investigate this matter so that the researcher can collect, analyze and provide an understanding of the data that has been collected. In making questions, the researcher used good language that was easy for respondents to understand when filling out the questionnaire distributed by the researcher later (Curran-Everett, 2018). This aims to ensure that respondents who provide responses to questions asked by researchers can be answered quickly. That way, it will be easier for researchers to test the data being investigated regarding Cognitive Improvement Through Non-Invasive Brain Stimulation Techniques in Healthy Adults

Research Subject

In researching cognitive enhancement through non-invasive brain stimulation techniques in healthy adults, researchers of course determine the subjects for their research. In this study, the subjects of this research were aimed at healthy adults who were randomly selected by researchers. Before the questionnaire was distributed by the researcher, the researcher first asked for the respondents' willingness to spend their time filling out the questionnaire that the researcher would distribute. The questionnaire each contains 10 questions that correspond to the topic of research discussion on Cognitive Improvement through Non-Invasive Brain Stimulation Techniques in Healthy Adults.

Research Ethics

To maintain public trust, ensure scientific validity, and protect the rights of people participating in research, research ethics are very important for researchers to maintain. Research ethics is known as a set of ethical principles that govern how people act and make decisions during research. The aim of this ethics is to ensure that research is conducted in a way that is fair, responsible, and respects the rights and welfare of all parties involved (Benjamin et al., 2019). In addition, researchers also provide actual information about their research to maintain their commitment. Researchers do this in order to obtain maximum research results, and remain consistent in developing better research patterns with the research they conduct.

Data Collection and Analysis

This time, the researcher used quantitative methods to collect research data. The researcher also used a T-test as previously mentioned by the researcher. The purpose of collecting this data is to find relationships and become a benchmark between the research object material entitled Cognitive Improvement through Non-Invasive Brain Stimulation Techniques in Healthy Adults. Researchers also carried out tests first using SPSS software to ensure that respondents' responses were very accurate and reliable. Thus, researchers must be very careful when collecting processed data (Liu et al., 2020).

Tabel 1

Categories of Cognitive Improvement Through Non-Invasive Brain Stimulation Techniques in Healthy Adults

No	Earning Category	Respondent Subject	Percentage (%)
1	Earning Category	Adults	>90%
2	Strongly agree	Adults	45-89%
3	Agree Disagree	Adults	15-30%
4	Disagree Don't agree	Adults	5-15%

Gambar 1

Data Collection and Analysis Flow

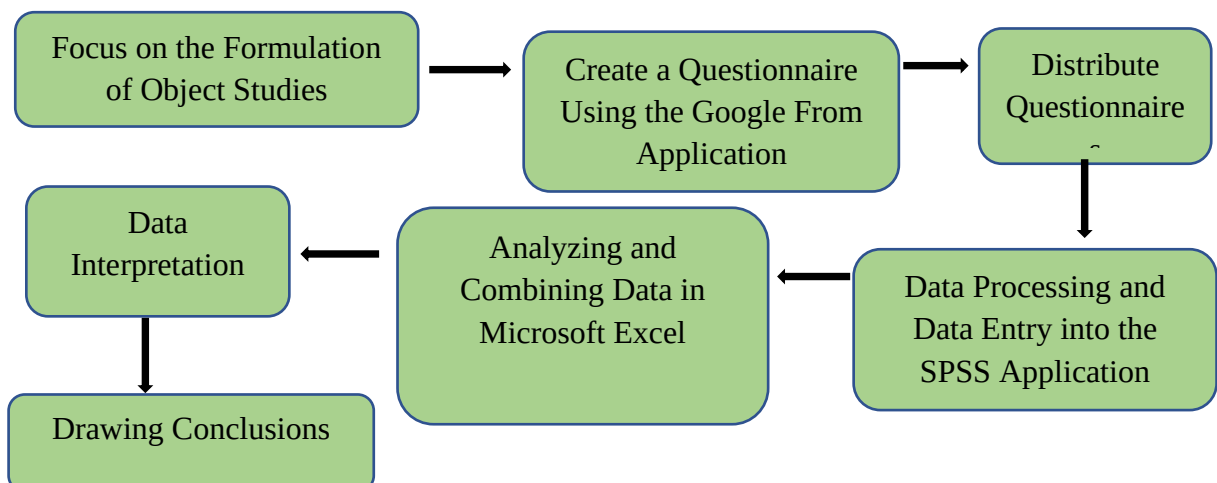


Figure 1 above shows how researchers collect and analyze research data. The results of data acquisition came from respondents' answers to the researcher's questions. Furthermore, in the quantitative research method, the researcher will also test again using the T-test which will be used to enter research data into the SPSS application. The number of questions asked by the researcher was 20 questions, where each question was divided into ten questions with different questions. Only after the questionnaire is distributed can researchers formulate and draw conclusions from the research object.

RESULTS

In the field of neuroscience, cognitive enhancement achieved by non-invasive brain stimulation techniques in healthy adults is an area of increasing interest. Transcranial magnetic stimulation (TMS), transcranial direct current stimulation (tDCS), and neurofeedback have all shown that they have the potential to achieve promising results. While tDCS uses low electric currents applied through electrodes on the scalp to modulate brain activity, which can also improve cognitive functions such as memory and attention, TMS uses magnetic fields to stimulate nerve cells in the brain. In contrast, neurofeedback involves using an EEG device to provide immediate feedback on brain activity. This allows people to train and change the way their brain activity works to improve their intelligence.

Table 2

Recap of Percentage Results from Respondents' Answers

No.	Question	strongly agree	Agree	Disagree	Don't Agree
1	Transcranial magnetic stimulation (TMS) can improve working memory performance in healthy adults.	52%	36%	12%	0%
2	Transcranial direct current stimulation (tDCS) has the potential to improve attentional function in individuals without neurological disorders.	67%	23%	5%	5%
3	Neurofeedback techniques may help improve self-regulation abilities in healthy adults.	31%	35%	34%	0%
4	Computer-based brain training combined with mild electrical stimulation can improve information processing speed.	80%	15%	5%	0%
5	Regular non-invasive brain stimulation can help maintain cognitive function as we age.	50%	50%	0%	0%
6	The use of tDCS can improve the ability to learn a new language in adults.	10%	10%	13%	67%

7	TMS targeted at Broca's area can improve language production ability in healthy individuals.	54%	31%	24%	9%
8	Non-invasive brain stimulation techniques can help improve creativity and problem-solving.	27%	27%	34%	12%
9	Neurofeedback can be used to improve sleep quality, which has a positive impact on cognitive function.	50%	34%	12%	4%
10	Combining tDCS with cognitive training may result in greater improvements than using either method alone.	46%	35%	24%	5%

Table 2 above shows the distribution of questionnaires that have been conducted by researchers. This questionnaire contains ten questions about cognitive improvement through non-invasive brain stimulation techniques in healthy adults. In addition, during the distribution of the questionnaire, the researcher has percented each response result from the respondents. Therefore, respondents can choose to answer the researcher's questions by providing options such as strongly agree, agree, disagree, or disagree. And it can also be seen from the first question asked by researchers regarding transcranial magnetic stimulation (TMS) can improve working memory performance in healthy adults, getting the highest score of 52% in the strongly agree option. The second question about transcranial direct current stimulation (tDCS) has the potential to improve attentional function in individuals without neurological disorders, obtained a percentage result of 67% in the strongly agree option.

The third question about neurofeedback techniques can help improve self-regulation skills in healthy adults, obtained a percentage result of 35% in the agree category. The fourth question about computer-based brain training combined with mild electrical stimulation can improve information processing speed, obtained a percentage of 80% in the strongly agree category. The fifth question Regular non-invasive brain stimulation can help maintain cognitive function as we age, received a percentage of 50% in the strongly agree and agree options. The sixth question The use of tDCS can improve the ability to learn new languages in adults, received a percentage of 67% who disagreed.

Furthermore, in the seventh question, TMS targeted at Broca's area can improve language production skills in healthy individuals, getting a percentage of 54% of the option choices strongly agree. In the eighth question regarding non-invasive brain stimulation techniques can help improve creativity and problem solving, obtained a percentage of 34% in the disagree category. The ninth question about Neurofeedback can be used to improve sleep quality, which has a positive impact on cognitive function, increasing their participation in therapy, got a percentage result of 50% in the strongly agree category. For the last question regarding the combination of tDCS with cognitive

training can produce greater improvement than the use of either method alone, getting a percentage of 46% in the option choice strongly agree.

Table 3

Recap of Percentage Results from Respondents' Answers

No.	Question	strongly agree	Agree	Disagree	Don't Agree
1	Non-invasive brain stimulation has the potential to improve overall quality of life through improved cognitive function in healthy adults	20%	30%	35%	15%
2	A combination of different non-invasive brain stimulation techniques may result in more comprehensive cognitive improvements	50%	50%	0%	0%
3	The use of non-invasive brain stimulation may help improve long-term memory	35%	45%	12%	8%
4	Non-invasive brain stimulation may help improve speed and accuracy in complex decision making	33%	56%	11%	0%
5	Non-invasive brain stimulation may help improve visuospatial abilities in adults	35%	24%	31%	10%
6	Transcranial Direct Current Stimulation (tDCS) technique has the potential to increase information processing speed	70%	20%	10%	0%
7	The use of tDCS may improve performance in tasks involving numerical processing	54%	32%	7%	7%
8	The safety of non-invasive brain stimulation techniques is generally high, with minimal side effects, such as a mild tingling sensation in the scalp	23%	32%	40%	5%
9	Further research is needed to understand the mechanisms behind how non-invasive brain stimulation can improve cognition in healthy adults	45%	38%	17%	0%
10	Response to non-invasive brain stimulation may differ between individuals, influenced by factors such as age and general health conditions	88%	10%	2%	0%

In the table 3 statement above, the researcher has also made ten questions. With a choice of options strongly agree, agree, disagree and disagree. Which can be seen

from the first question regarding non-invasive brain stimulation has the potential to improve overall quality of life through improved cognitive function in healthy adults, getting a percentage result of 35% in the option to disagree. Next question number two about The combination of various non-invasive brain stimulation techniques can result in more comprehensive cognitive improvement, getting a percentage score of 50% on the choice of options strongly agree and agree. The third question about The use of non-invasive brain stimulation can help improve long-term memory, received a percentage score of 45% in the agree option.

The fourth question about non-invasive brain stimulation can help improve speed and accuracy in complex decision making, got a percentage of 56% percentage score on the option choice of agree. The fifth question about non-invasive brain stimulation can help improve visuospatial abilities in adults, got 35% of the option choices strongly agree. The sixth question about Transcranial Direct Current Stimulation (tDCS) technique has the potential to increase the speed of information processing, getting a percentage gain of 70% on the option choice strongly agree.

Furthermore, the seventh one regarding The use of tDCS can improve performance in tasks involving numerical processing, received a percentage score of 54% on the option choice strongly agree. The eighth question about The safety of non-invasive brain stimulation techniques is generally high, with minimal side effects, such as a mild tingling sensation on the scalp, getting a percentage gain of 40% on the option choice of less agree. In question nine that more research is needed to understand the mechanisms behind how non-invasive brain stimulation can improve cognition in healthy adults, gained a percentage of 45% from the strongly agree category. The last question about Response to non-invasive brain stimulation can differ between individuals, influenced by factors such as age and general health condition, received a percentage of 88% in the strongly agree option.

Diagram 1

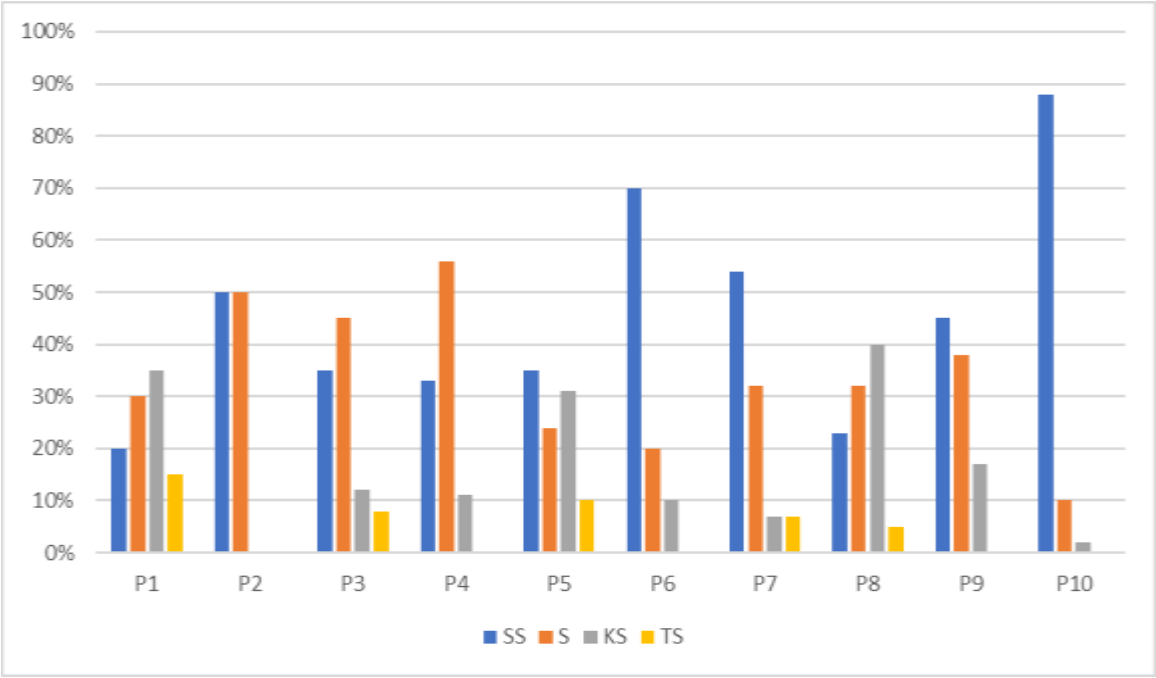


Diagram 2

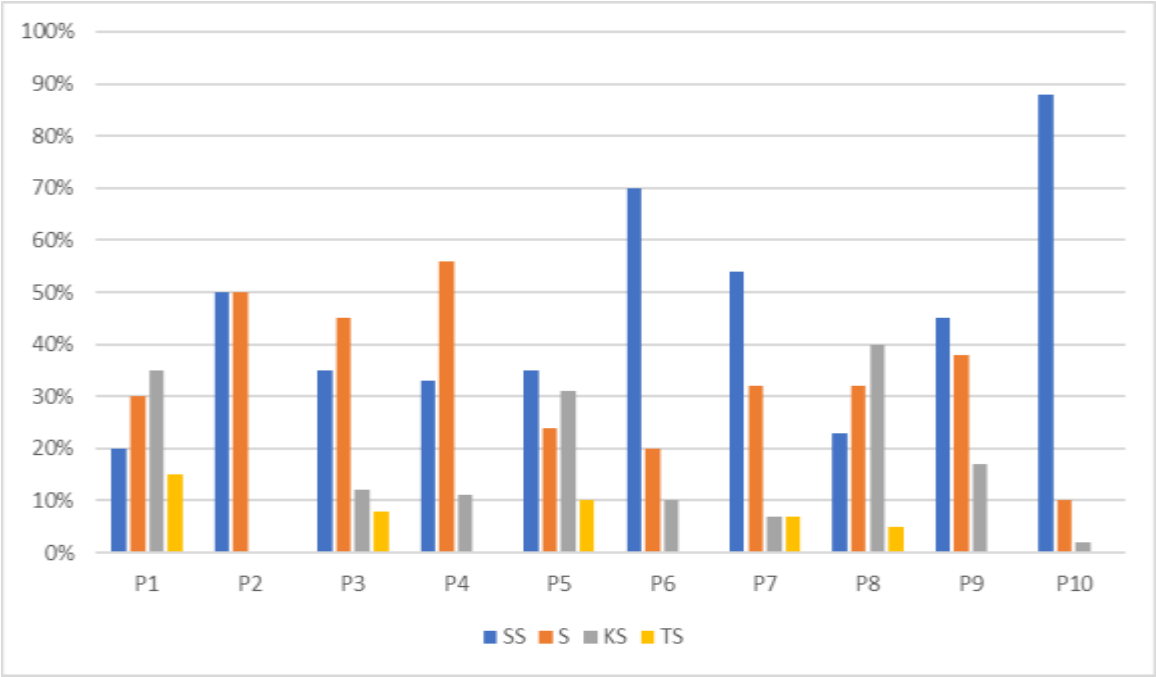


Table 3

T-test of cognitive improvement through non-invasive brain stimulation techniques in healthy adults

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRE TEST	46.0000	20	20.06306	4.48624
	POST TEST	31.6500	20	12.65025	2.82868

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	PRE TEST & POST TEST	20	-.268	.254

Paired Samples Test

		Paired Differences			95% Confidence Interval of the Difference	
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper
Pair 1	PRE TEST - POST TEST	14.35000	26.42621	5.90908	1.98215	26.71785

Based on the results of table 3 above, it is a T-test using the SPSS application. From the results of the study, researchers can conclude that the T-test test in the first output section explains Mean as an average. In the Pre Test, the resulting average amount was 46.0000, while in the Post Test it was 31.6500. Based on these results it can be formulated that there is a difference from the results of the respondents' answers. Furthermore, in the Paired Samples Correlations section, obtaining Correlations of -.268, as well as a large sig acquisition of .254. Furthermore, in the Paired Samples Test section, the results obtained are 26.42621 in the Std. Deviation section, while in the Std. Error Mean section obtained a result of 5.90908. Based on these results, cognitive improvement through non-invasive brain stimulation techniques in healthy adults.

Table 4

T-test on cognitive improvement through non-invasive brain stimulation techniques in healthy adults

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRE TEST	16.4000	20	12.74197	2.84919
	POST TEST	7.3500	20	14.80140	3.30969

Paired Samples Correlations

				N	Correlation	Sig.
Pair 1	PRE TEST & POST TEST			20	.128	.592

Paired Samples Test

				Paired Differences				
				Mean	Std. Deviation	Std. Error	95% Confidence Interval Difference	
Pair 1	PRE TEST - POST TEST			9.05000	18.25687	4.08236	.50552	Upper

Furthermore, in table 4, it is also the result of research using the T-test. It can be seen in the first output section from the acquisition of the Pre Test results of 16.4000, and the Post Test of 7.3500. In the Paired Samples Correlations section, obtaining Correlations of .128, with the acquisition of Sig results of .592. While in the Paired Samples Test section, obtained results of 18.25687 in the Std. Deviation, and Std. Error Mean of 4.08236. Based on the results of this study, it can be seen between each question asked by researchers regarding cognitive enhancement through non-invasive brain stimulation techniques in healthy adults.

DISCUSSION

In recent years, non-invasive brain stimulation techniques for cognitive enhancement have become an increasingly popular subject of research (Ahmed et al., 2023). In these methods, devices such as Transcranial Direct Current Stimulation (tDCS) and Transcranial Magnetic Stimulation (TMS) can be used to influence brain activity without having to undergo surgical procedures. tDCS sends low electric currents through electrodes placed on the scalp to stimulate or inhibit neuronal activity in specific areas of the brain. TMS, on the other hand, uses magnetic fields to stimulate neurons in targeted areas of the brain (Fröhlich & Lustenberger, 2020). Both methods have been shown to improve the cognitive abilities of healthy adults, including memory, attention, and problem-solving abilities. Research shows that non-invasive brain stimulation can significantly improve intelligence (Dell'Osso & Di Lorenzo, 2020). For example, a study involving stimulation sessions over several weeks found that tDCS could improve participants' memory retention and learning ability. In the same way, TMS has been shown to improve attention and executive abilities in terms of planning and decision-making (Begemann et al., 2020).

The use of non-invasive brain stimulation techniques for cognitive enhancement requires further research to ensure that they are safe and effective in the long term

(Brighina et al., 2019). Individual response variability, which can be affected by variables such as age, genetics, and general health conditions, is a key issue (Guerra et al., 2020). There is also a need to understand more about how this stimulation affects brain function. To find the best stimulation protocol and reduce the side effects of long-term use, further research is needed. In addition, it is important to consider the ethics of using non-invasive brain stimulation to improve intelligence (Lewis et al., 2021). Although this method can significantly improve cognitive performance, there is a possibility of its misuse, especially in terms of non-medical matters such as improving academic or professional performance (Cassani et al., 2020). Therefore, strict regulations and moral standards are essential to ensure that these technologies are used responsibly.

Non-invasive brain stimulation (NIBS) methods can stimulate brain activity without surgical procedures. Some of these methods, such as Transcranial Direct Current Stimulation (tDCS) and Transcranial Magnetic Stimulation (TMS), work by directing electric currents or magnetic fields to the scalp to influence neuronal activity in specific areas of the brain (Westwood et al., 2021). The use of this method in healthy adults has shown the potential to produce greater effects. Studies on the use of NIBS in healthy adults show promising cognitive improvements (Yamada & Sumiyoshi, 2021). For example, studies have shown that regular tDCS sessions can improve participants' ability to learn and short-term memory. In contrast, TMS has been shown to improve planning, decision-making, and other functions that executives need. Stimulation aids in the adjustment and strengthening of synaptic connections in the brain, which supports more efficient cognitive processes, which is thought to be the cause of these effects (Mishra & Thrasher, 2021). However, the response to NIBS may differ from person to person, influenced by age, genetics, and general medical conditions.

Further research is needed to understand the mechanisms behind how stimulation affects brain function and cognition, as well as to identify components that may influence an individual's response to stimulation (Kim et al., 2022). One of the main challenges is determining the ideal stimulation protocol to achieve the desired results without causing unwanted side effects (Siebner et al., 2022). The use of NIBS to enhance cognitive abilities must also be considered ethically. Misuse of this technology may occur in non-medical contexts, such as to disproportionately enhance academic or professional performance. Therefore, strict regulations and moral standards are essential to ensure that these technologies are used responsibly (Horn et al., 2019). NIBS can be a powerful tool to support cognitive enhancement in healthy adults with proper research and good regulation. This will help them achieve higher cognitive potential without taking significant risks.

cognitive enhancement through (NIBS) techniques has been the subject of interesting research (Casula et al., 2023). Methods such as Transcranial Direct Current Stimulation (tDCS) and Transcranial Magnetic Stimulation (TMS) use the scalp to deliver electric currents or magnetic fields to the brain to stimulate or inhibit neuronal activity (Huo et al., 2021). This technique has been shown to improve memory,

attention, and problem-solving abilities in healthy adults. Early results are very promising for the use of NIBS for cognitive enhancement, but more research is needed to ensure that it is safe and effective in the long term (Fitzgerald et al., 2021). Determining the ideal stimulation protocol and understanding the underlying mechanisms of how stimulation affects the brain are big issues. NIBS has great potential to be an effective tool to support cognitive improvement in healthy adults with proper regulation and ongoing research (Hernando et al., 2020).

CONCLUSIONS

Non-invasive brain stimulation (NIBS) techniques, such as Transcranial Direct Current Stimulation (tDCS) and Transcranial Magnetic Stimulation (TMS), can improve cognitive function of healthy adults. Studies have shown that these techniques can improve memory, attention and problem-solving ability with low levels of safety and side effects. However, further research is needed to understand the underlying mechanisms and ensure that this stimulation is effective and safe in the long term. To prevent misuse, the ethical aspects of using NIBS in non-medical contexts should also be carefully considered. Strict regulations should be implemented to ensure that this technology is used responsibly. NIBS may be a safe and effective tool to support cognitive enhancement in healthy adults, helping them achieve higher cognitive potential with the support of ongoing research and sound regulation.

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