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Research Paper

Comparing the Effectiveness of Mindfulness Meta-Cognitive Therapy vs Transcranial Direct Current Stimulation in People With General Anxiety Disorder

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ABSTRACT

Objective: This study compares the effectiveness of mindfulness meta-cognitive therapy and transcranial direct current stimulation (tDCS) on experiential avoidance, negative strategies of cognitive emotion regulation, and emotional processing in people with general anxiety disorder (GAD).

Methods: This was a semi-experimental research with experimental and control groups. A total of 45 patients with GAD were selected using the purposeful sampling method. One group received 8 sessions of mindfulness meta-cognitive therapy (one session per week), and another group received 15 sessions of tDCS (three sessions per week; each session was 20 min in F_3/F_4 with an intensity of 2 mA). All subjects in two treatment groups and one waitlist control group were evaluated before and after the treatment using an acceptance and action questionnaire, cognitive emotion regulation questionnaire, and emotional processing scale. The data were analyzed by multivariate analysis of covariance and the Tukey test. The data were analyzed using the SPSS software, version 19.

Results: The results showed that tDCS and mindfulness meta-cognitive therapy are effective in experiential avoidance ($F=98.53$, $\eta^2=0.744$), negative strategies for cognitive emotion regulation ($F=102.26$, $\eta^2=0.824$), and emotional processing ($F=121.26$, $\eta^2=0.931$) in people with GAD. There is no significant difference in the experiential avoidance variable (md=0.735, P=0.575) and emotional processing (md=0.731, P=0.134) between mindfulness meta-cognitive therapy and tDCS therapy; however, in the rumination subscale, only mindfulness meta-cognitive therapy treatment method has been effective in the variable of negative strategies of cognitive emotion regulation (md=4.63, P=0.008).

Conclusion: tDCS and mindfulness meta-cognitive therapy were both effective in improving GAD symptoms, but mindfulness meta-cognitive therapy had more effects on clients' rumination. As a result, to control the negative strategies for cognitive emotion regulation, mindfulness meta-cognitive therapy has a better effect.

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Highlights

- Transcranial direct current stimulation (tDCS) and mindfulness meta-cognitive therapy were effective in people with general anxiety disorder (GAD).

- There was no significant difference in the experiential avoidance variable between mindfulness meta-cognitive and tDCS therapy.

- There was no significant difference in emotional processing between mindfulness meta-cognitive therapy and tDCS therapy.

- In the rumination subscale of negative strategies of cognitive emotion regulation variable, only mindfulness meta-cognitive therapy treatment method has been effective.

Plain Language Summary

Anxiety disorder is one of the most severe mental health problems in life. Anxiety symptoms are common and significantly interfere with people's daily lives. Anxiety significantly impairs cognition and willingness to endure upsetting emotions. Higher emotional reactivity in general anxiety disorder makes it challenging to regulate emotions. This study examines the effects of mindfulness meta-cognitive therapy vs transcranial direct current stimulation on the three variables of experiential avoidance, negative strategies on cognitive emotion regulation, and emotional processing. This study investigates which variables better affect these two treatment methods. Findings show that mindfulness meta-cognitive therapy had a better outcome in reducing negative strategies of cognitive emotion regulation in general anxiety disorder.

Introduction

One of the severe and common mental health problems is related to anxiety disorder, and every year, it imposes enormous costs on society (Mash & Woolf, 2012). People with general anxiety disorder (GAD) have uncontrollable worries which last at least six months. In addition, people with GAD have other symptoms, such as fatigue, low concentration, irritability, and sleep problems (DeMartini et al., 2019). One of the psychological components in people suffering from anxiety disorders is a defect in emotion regulation strategies (Rabie et al., 2013).

Individuals with GAD usually avoid their painful feelings and negative thoughts and try to suppress them and stay away from doing many of their activities. This negative reaction leads to experiential avoidance (Hayes-Skelton et al., 2013). Experiential avoidance involves an unwillingness to endure upsetting emotions, thoughts, memories, and other private experiences. Such unwillingness leads to maladaptive efforts to resist, escape, and avoid distressing and disturbing experiences in people's lives (Hayes et al., 1996). Past research has shown that experiential avoidance is the cause of anxiety disorders, especially GAD (Hayes et al., 1996; Orsillo & Roemer, 2005). Although experiential avoidance alleviates distress in the short term, its prolonged use underlies a variety of dysfunctional conditions in adults, including avoidant coping styles, excessive thought suppression, drug or alcohol use to escape from unwanted moods, and avoidance of feared objects, places, or situations (Chawla & Ostafin, 2007).

Evidence shows that negative emotion regulation strategies are related to anxiety disorders (Ghasempour, 2012). Higher emotional reactivity in GAD disorder makes it difficult to regulate emotions, and this fosters complications by making it challenging to identify and understand emotions (Mennin, 2004). Emotion regulation refers to the processes that influence the intensity, duration, and expression of emotions (Gross & Thompson, 2007), and effective emotion regulation can reduce the intensity of negative emotional responses in anxiety-provoking situations. Research has shown a strong relationship between the emotional problems of people of different ages and self-blame, catastrophizing, and rumination as cognitive emotion regulation strategies (Garnefski & Kraaij, 2006). This issue shows that people's vulnerability to negative and uncomfortable events increases with negative strategies of cognitive emotion regulation (Garnefski et al., 2002).

Anxious people have problems in cognitive processing because anxiety strongly affects cognition (Bar-Haim et al., 2011). The level of anxiety of a person affects the level of cognitive processing of emotional information. Also, anxiety reduces the activity of the prefrontal cortex, and as a result, it causes disturbances in attention (Bishop, 2009) and a lack of control during emotional processing (Osinsky et al., 2012).

Meta-cognitive therapy is a meta-diagnostic therapy and shows that psychopathology is related to cognitive attentional syndrome (CAS) (Wells, 2009). CAS is defined as rumination, ineffective coping styles such as thought suppression, avoidance, repetitive worries, and threat-oriented attention. A more recent one that seems to look specifically at GAD is meta-cognitive therapy (Wells, 2009). Positive and negative meta-cognitive beliefs influence CAS. People with positive meta-cognitive beliefs maintain that having these thoughts is beneficial, and this issue increases a series of repeated negative thoughts. When people engage in repetitive thoughts, negative meta-cognitive beliefs are activated. People conclude that their repetitive thoughts are uncontrollable and harmful at this stage. They begin to worry about their thoughts. A vicious cycle is created where people cannot control their thoughts, no matter how hard they try.

Mindfulness meta-cognitive therapy (MCT) was derived from the meta-cognitive model proposed by Efklides (2008). Efklid's model was in harmony with the cognitive and meta-cognitive processes used in mindful information processing. This method expresses the mindfulness state as originally proposed by Kabat-Zinn. This method helps to understand the process in a person's mind in mindfulness. Meta-cognition is used in the classical definition of mindfulness (Kabat-Zinn, 2003). In this definition, the conscious mind is defined as a form of consciousness caused by a change in the content of consciousness and includes thoughts, feelings, images, and perceptions. Mindful people are familiar with metacognition, and this issue reduces the possibility of anxiety and depression recurrence (Teasdale et al., 2002; Watkins et al., 2000). As a result, mindfulness can be conceptualized in terms of meta-cognition (Jankowski & Holas, 2014).

Transcranial direct current stimulation (tDCS) transmits mild electric current continuously to the scalp and applies a neuro-modulatory effect. Anodal tDCS increases, and cathodal tDCS decreases cortical excitability (Liebetanz et al., 2002). Functional magnetic resonance imaging (fMRI) has shown that positive emotional stimulation, compared to negative emotional stimulation, can increase the dorsolateral prefrontal cortex (dlPFC) (Dolcos et al., 2004).

The prefrontal cortex plays an important role in regulating positive and negative emotions due to its connection with subcortical regions, such as the amygdala and the nucleus accumbens (Sotres-Bayon et al., 2010). Specifically, when a person is involved in negative emotions, dlPFC is one of the brain's regions involved in processing (Davidson et al., 2000). Research shows that left dlPFC activity is involved in anxiety regulation (Bishop, 2007). Also, findings demonstrate that dlPFC tDCS of the left anodal region causes people to show less emotional reaction to negative content (Peña-Gómez et al., 2011), facilitates attentional control for purposeful cognition (Martin et al., 2013), and attentional vigilance reduces to threat (Heeren et al., 2017).

This study examines the effect of MCT on experiential avoidance, negative emotion regulation strategies, and emotional processing in people with GAD, investigates the impact of tDCS on experiential avoidance, negative emotion regulation strategies, and emotional processing in people with GAD, and compares MCT and tDCS on experiential avoidance, negative emotion regulation strategies, and emotional processing in people with GAD. Based on previous studies, these two treatments are effective for GAD; however, this study compares the two treatment and their effects. In addition, this research investigates which variables have a better impact on these two treatment methods.

Materials and Methods

This was a semi-experimental study with experimental and control groups with a pre-test/post-test design. The statistical population of this study included subjects with GAD in Tehran, Iran, who were referred to Tehran clinics in 2019-2020. The sample consisted of 45 patients with GAD, of which 15 people were in the group under the treatment with MCT, 15 were in the group under the treatment of tDCS, and 15 were in the control group. People were randomly divided into three groups using stratified randomization considering gender. The sample size was selected, considering this is an experimental study and is also similar to previous research. The selection of subjects was purposeful, and they were treated according to the following criteria. The admission criteria were having GAD according to The diagnostic and statistical manual of mental disorders, fifth edition, not undergoing any psychotherapy for the past three months, no infection or other psychiatric disorders, no substance abuse, having 18 to 50 years of age, and having at least a high school diploma level. Meanwhile, the exclusion criteria were failure to meet the diagnostic and statistical manual of mental disorders, fifth edition diagnostic

criteria for GAD, having a history of epilepsy and mental retardation, and taking anxiety medications during the study. Clients with GAD, who were evaluated by a generalized anxiety disorder-7 (GAD-7) questionnaire and scored 10 or higher, were included in the sample. Also, 40% (n=18) of the sample were female, and 60% (n=27) were male, with a Mean±SD age of 37.56±4.46 years. All samples were from Iran.

The therapist was the first author of this article. The therapist was trained in comprehensive MCT and tDCS treatment workshops separately.

Study instruments

Generalized anxiety disorder questionnaire

GAD-7 is a 7-item questionnaire designed to evaluate the level of anxiety of patients in the last two previous weeks. The items enquire about the amount of nervousness and anxiety that bothers the patient, the patient's inability to control and stop their worries, worrying too much about different things, difficulty in calming themselves, being restless for fear of something happening, getting angry, feeling afraid easily, and easily collapsing (Spitzer et al., 2006).

The scores are then totaled and presented from 0 to 21 (based on a 3-point Likert scale). The 5, 10, and 15 scores represent cut-off points for mild, moderate, and severe anxiety, respectively. This questionnaire had good internal consistency (Cronbach α=0.79–0.91). In the Iranian sample, the validity of the correlation between this scale and trait anxiety inventory and anxiety subscale of symptom checklist-90 were 0.71 and 0.63, respectively. Also, the Cronbach α coefficient for the research sample was 0.85 (Naeinian et al., 2011).

Acceptance and action questionnaire–II

The acceptance and action questionnaire-II (AAQ-II) (Bond et al., 2011) contains 10 questions. Each question evaluates the person based on a 7-point Likert scale. The range of AAQ-II score is from 10 to 70. Higher scores indicate more acceptance and less avoidance. The Dutch AAQ-II (Jacobs et al., 2008) showed good internal consistency (Cronbach α=0.85). The Cronbach α of the Persian version of this questionnaire for the general population is 0.82, and for the GAD group is 0.84. The validity of the correlation between this scale and general health questionnaire-28, Beck anxiety inventory, and Beck depression inventory were -0.62, -0.44, and -0.59, respectively (Abasi et al., 2013).

Cognitive emotion regulation questionnaire

The cognitive emotion regulation questionnaire (CERQ) measures the cognitive strategies of emotion regulation. It evaluates the reaction of people facing stressful and life-threatening events (Garnefski et al., 2002). CERQ assesses 9 subscales in 36 questions. Each subscale contains 4 items. Meanwhile, its 9 subscales are catastrophizing, rumination, positive refocusing, positive reappraisal, self-blame, other-blame, acceptance, and planning. This study examined negative cognitive emotion regulation strategies (self-blame, other-blame, rumination, catastrophizing). This questionnaire measures cognitive emotion regulation strategies based on a 5-point Likert scale. The scoring degree is from almost never (1) to almost always (5). Previous research has shown that in this questionnaire, all subscales have good internal consistency (0.68-0.86) (Garnefski et al., 2002). In the Iranian sample, the reliability of the questionnaire using the Cronbach α coefficient for all cognitive scales is reported at 0.76. The validity of this questionnaire was obtained by the factor analysis method (KMO=0.82) (Hasani, 2010).

Emotional processing scale

The emotional processing scale (EPS) examines emotional processing styles and includes 38 items. This questionnaire was created to measure emotional processing and has changed over time so that therapists can use it (Baker et al., 2007). It uses a 10-point Likert scale, and higher scores indicate more problems in emotional processing. This questionnaire includes 8 subscales. Accordingly, 4 subscales are related to the control mechanism of experience and emotional expression (suppression, uncontrolled, dissociation, avoidance). One subscale is related to insufficient emotional processing (intrusion), and the other three are related to capturing emotional experience (lack of attunement, externalized, discordant). Good internal validity has been reported for EPS. This scale's Cronbach α coefficient and test-retest reliability were reported at 0.92 and 0.79, respectively (Baker et al., 2007). In the Iranian sample, the Cronbach α coefficient for the whole scale and subscales are calculated at 0.95 and 0.85, respectively. The correlation coefficient of this scale with the emotion regulation scale was -0.054 (P>0.01) (Lotfi et al., 2013).

Mindfulness meta-cognitive therapy

All subjects in the meta-cognitive therapy group underwent 8 sessions of MCT. Individual treatment was performed on 15 members of the meta-cognitive therapy group in eight 1-h sessions (one session per week). The

Table 1. Content of mindfulness meta-cognitive therapy sessions

Session	Content
1	Explaining the objectives of the meeting, explanation of interventions, detached mindfulness based on metacognitive, providing assignments at home
2	Reviewing the assignments of the previous session, explanation of the attention program task and its implementation, providing assignments at home
3	Reviewing the assignments of the previous session, detached attention, and meta-cognitive guidance techniques training, in addition to providing assignments at home
4	Reviewing the assignments of the previous session, free association training and management of unruly children and suppression of anti-repression, and providing assignments at home
5	Reviewing the assignments of the previous session, tiger task and imagery of passing clouds techniques training, application of train station technique, and providing assignments at home
6	Reviewing the assignments of the previous session, see yourself and verbal loop training by using detached attention, and providing assignments at home
7	Reviewing the assignments of the previous session, imagination and looking at the thoughts training, train station techniques, and providing assignments at home
8	Reviewing the assignments of the previous session, summarizing, and final answer to the patient's questions

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sessions were conducted in person. At first, case formulation was performed, and the participants were acquainted with this model. Next, positive and negative meta-cognitive beliefs were identified. According to MCT, attention training, detached mindfulness, and free association techniques were used for treatment in sessions.

The following items were practiced during MCT sessions (Nazaribadie et al., 2020):

Transcranial direct-current stimulation

This research applied direct electrical current to the subject's scalp through a battery that transmits a constant current. This electrical current was transmitted through 5×7 cm sponge electrodes soaked in salt (Neuroconn, GmbH, ilmenau, Germany). Electrodes were placed on the subjects' heads according to the 10-20 system. During treatment, the anode was placed on the left prefrontal (F_3), and the cathode was placed on the right prefrontal (F_4). We used bilateral stimulation over the dlPFC in this study. Right, dlPFC and left dlPFC were the only targeted regions in the previous studies that aimed to regulate anxiety disorders using tDCS. Also, in some studies, excitatory stimulation of the left dlPFC (Pena-Gomez et al., 2011) and, in others, inhibitory stimulation over the right dlPFC (De Raedt et al., 2010) were effective in reducing negative emotions. As a result, in this study, we examined bilateral stimulation, which might enhance the efficacy of interventions. Active tDCS consisted of a constant current of 2 mA for 20 min in 15 sessions. Individual treatment sessions were performed on 15 subjects of the tDCS therapy group. It was a 5-week intervention (three sessions per week). All subjects were told to sit quietly and regulate their breathing.

Study procedures

First, the subjects were selected via the purposeful sampling method. They were assessed using the GAD-7 questionnaire (participants who scored 10 or higher), and their degree of compliance with the inclusion and exclusion criteria was determined. All subjects (n=45) were evaluated by AAQ-II, CERQ, and EPS (pre-test). In the next step, the subjects were randomly assigned into two treatment groups, namely MCT and tDCS, and a control group using stratified randomization considering gender (each group consisted of 15 subjects). The MCT group received 8 sessions of therapy once a week. The tDCS group received fifteen sessions of therapy three times a week. The first author of this article conducted therapeutic sessions in Tehran, Iran. Finally, after treatment, a post-test was done. The post-test consisted of AAQ-II, CERQ, and EPS (the raters who completed the pre-and post-test assessments were blinded to the study). Then, the results were analyzed using the SPSS software, version 19. The subjects were fully aware of the research, and all ethical considerations were observed.

Analytic plan

In this study, according to the type of variables and dimensions of the study to investigate the therapeutic effects of MCT and tDCS, analysis of covariance was used to compare variables related to anxiety before and after treatment (experiential avoidance, negative emotion regulation strategies, and emotional processing). The effectiveness of MCT and tDCS were independent variables, and the degree of experiential avoidance, negative emotion regulation strategies, and emotional processing measured after treatment (post-test) were dependent variables. The

Table 2. Multivariate test of the effect of MCT and tDCS on general anxiety disorder

Independent Variables	Test	Value	F	Sig.	η^2
Treatment method	Pillais trace	0.721	4.704	0.0005	0.402
	Wilks lambda	0.678	6.314	0.0005	0.543
	Hotelling trace	1.234	6.978	0.0005	0.604
	Roy largest root	1.320	22.31	0.0005	0.889

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covariate variables were the pre-test (AAQ-II, CERQ, and EPS) that calculated the experiential avoidance, negative emotion regulation strategies, and emotional processing before treatment. Anxiety intensity (having a score of 10 or higher in GAD-7) was also controlled.

To evaluate and compare the effects of the two treatment methods, multivariate analysis of covariance and the Tukey test was used for analysis. The Tukey test was used to compare pairs. First, MCT and tDCS were compared for the experiential avoidance variable. Second, the two treatments were compared for the negative emotion regulation strategies variable. Third, they were compared for the emotional processing variable.

Results

In this study, 40% (n=18) of the sample were female, while 60% (n=27) were male, with a Mean±SD age of 37.56±4.46 years.

The effect of mindfulness meta-cognitive therapy and transcranial direct-current stimulation on general anxiety disorder

Table 1 presents the results of a multivariate analysis of covariance to evaluate the effect of MCT and tDCS on experiential avoidance, negative strategies of cognitive emotion regulation, and emotional processing in people with GAD. According to Table 2, the results of the Pillais trace, Wilks lambda, Hoteling trace, and Roy largest root at a significance level of 0.0005 equal 4.704, 6.314, 6.978, and 22.3, respectively. These results showed that MCT and tDCS were effective in experiential avoidance, negative strategies of cognitive emotion regulation, and emotional processing in people with GAD. In other words, the results indicate a significant difference between MCT, tDCS, and control groups, at wleast in one of the variables of experiential avoidance, negative strategies of cognitive emotion regulation, and emotional processing.

According to the results of Table 3, the effect of MCT and tDCS on the variables of experiential avoidance, negative strategies of cognitive emotion regulation, and emotional processing at the level of significance 0.0005, according to F, are 98.531, 102.263, and 121.26, respectively. Considering the η^2, 74.4% of the changes in experiential avoidance, 82.4% in negative strategies of cognitive emotion regulation, and 93.1% of changes in emotional processing are due to MCT and tDCS.

Couple comparison of mindfulness meta-cognitive therapy and transcranial direct-current stimulation

Table 4 shows no significant difference in the experiential avoidance variable between the treatment methods, MCT, and tDCS, according to the mean difference (0.735) and the significance level (P=0.575). There is a significant difference between the MCT and control groups, with a mean difference of 3.66 and a significance level of P=0.003. In addition, there is a significant difference between the tDCS and control groups, with a mean difference of 5.23 and a significant level of P=0.002 (P≤0.05). In other words, both treatments significantly affected the experiential avoidance of GAD (according to the mean difference between MCT and the control group, which is 3.66, while the mean difference between tDCS and the control group is 5.23).

According to Table 5, no significant difference exists in the self-blame, other-blame, and catastrophizing variables between MCT and tDCS, according to the mean difference (1.26, 0.37, 0.265) and the level of significance (P≤0.05). There is a significant difference between the MCT and control groups in the self-blame, other-blame and catastrophizing variables (P=0.005, 0.002, 0.002). Also, there is a significant difference between the tDCS and control group in the self-blame, other-blame, and catastrophizing (P=0.006, 0.003, 0.002).

Table 3. Differential results of multivariate analysis of covariance of MCT, tDCS, and control groups

Dependent Variables	Measures	Sum of Squares	df	Mean Square	F	Sig.	η^2
Experiential avoidance	Pre-test	184.541	2	184.541	29.248	0.0005	0.302
	Group	521.240	2	521.240	98.531	0.0005	0.744
	Error variance	124.201	26	6.981			
	Total variance	648.204	29				
Negative strategies of cognitive emotion regulation	Pre-test	252.520	2	252.520	30.202	0.0005	0.342
	Group	894.310	2	894.310	102.263	0.0005	0.824
	Error variance	195.360	26	7.312			
	Total variance	720.724	29				
Emotional processing	Pre-test	384.301	2	384.301	31.803	0.0005	0.371
	Group	1109.612	2	1109.612	121.261	0.0005	0.931
	Error variance	302.434	26	12.324			
	Total variance	642.251	29				

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According to Table 5, there is a significant difference in the rumination variable between the treatment methods, MCT, and tDCS, according to the mean difference (4.63) and the significance level (P=0.008). There is a significant difference between the MCT and the control groups, with a mean difference of (4.741) and a significance level of P=0.003. There is no significant difference between the tDCS and control groups, with a mean difference of 0.276 and a significance level of P=0.224 (P≤0.05). In other words, MCT treatment significantly affected the rumination with GAD, but tDCS had no significant impact on the rumination.

According to Table 5, there is no significant difference in the negative strategies of cognitive emotion regulation variable between the two treatment methods (MCT and tDCS) according to the mean difference of 0.124 and the significance level (P=0.410). There is a significant difference between the MCT and control groups, with a mean difference of 10.394 and a significance level of P=0.007. In addition, there is a significant difference between the tDCS and control groups, with a mean difference of 9.974 and a significance level of P=0.006 (P≤0.05). In other words, both treatments had a significant effect on the negative strategies of cognitive emotion regulation with GAD.

Table 6 shows no significant difference in the emotional processing between MCT and tDCS, according to the mean difference (0.731) and the significance level (P=0.134). There is a significant difference between the MCT and control groups, with a mean difference of 7.80 and a significant level of P=0.000. In addition, there is a significant difference between the tDCS and control groups, with a mean difference of 9.01 and a significant level of P=0.000 (P≤0.05). In other words, both treat-

Table 4. Tukey test results for comparison of groups in experiential avoidance

Dependent Variable	Group	Groups	Mean Difference	Standard Error	P
Experiential avoidance	MCT	tDCS	0.735	0.121	0.575
		Control	-3.66	3.024	0.003
	tDCS	Control	-5.23	4.482	0.002

MCT: Mindfulness meta-cognitive therapy; tDCS: Transcranial direct-current stimulation.

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Table 5. Tukey test results for comparison of groups in negative strategies of cognitive emotion regulation

Dependent Variables	Group	Groups	Mean Difference	Standard Error	P
Self-blame	MCT	tDCS	-1.26	0.941	0.302
		Control	-7.42	3.57	0.005
	tDCS	Control	-6.64	3.46	0.006
Other-blame	MCT	tDCS	-0.37	0.219	0.821
		Control	-7.27	4.08	0.002
	tDCS	Control	-6.41	3.841	0.003
Rumination	MCT	tDCS	-4.63	3.024	0.008
		Control	-5.81	4.741	0.003
	tDCS	Control	-0.98	0.276	0.224
Catastrophizing	MCT	tDCS	-0.265	1.836	0.741
		Control	-6.34	3.751	0.002
	tDCS	Control	-5.71	4.249	0.002
Negative strategies of cognitive emotion regulation	MCT	tDCS	-0.124	0.617	0.410
		Control	-10.394	4.824	0.007
	tDCS	Control	-9.974	4.671	0.006

MCT: Mindfulness meta-cognitive therapy; tDCS: Transcranial direct-current stimulation.

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ments had a significant effect on the emotional processing with GAD (according to the mean difference between MCT and control group which is 7.80 while the mean difference between tDCS and control group is 9.01).

Discussion

Although there is considerable evidence that MCT and tDCS are effective in GAD, this study is the first to compare the effectiveness of these two treatments and the variables each treatment method affects. Consequently, it is imperative to understand better the difference in effectiveness of the two treatment and their implications. The results indicate that both treatments (MCT and tDCS) are effective in experiential avoidance and emotional processing; however, in the rumination subscale, only the MCT treatment method has been effective. Therefore, in the negative strategies of cognitive emotion regulation variable, MCT treatment has been more effective than tDCS. The differences observed can be accounted for by the different focus and techniques used in these therapies. Thus, the specific elements in each therapy seem to play an important role.

Table 6. Tukey test results for comparison of groups in emotional processing

Dependent Variable	Group	Groups	Mean Difference	Standard Error	P
Emotional processing	MCT	tDCS	-0.731	0.463	0.134
		Control	-7.80	5.82	0.000
	tDCS	Control	-9.01	6.01	0.001

MCT: Mindfulness meta-cognitive therapy; TDCS: Transcranial direct-current stimulation.

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Experiential avoidance is a person's avoidance of painful events, experiences, thoughts, feelings, and memories (Hayes et al., 2004). As its useful counterpart, mindfulness is non-judgmental, purposeful attention in the present moment (Kabat-Zinn, 1990). Many types of research show that mindfulness reduces anxiety because mindfulness reduces experiential avoidance (a person is less likely to avoid unpleasant experiences), and this helps control anxiety (McCluskey et al., 2022). Mindfulness and experiential avoidance represent constructs that influence the experience of emotions (Dimidjian & Linehan, 2003). Negative reinforcement and avoidance processes contribute extensively to the etiology and maintenance of many clinical disorders. MCT emphasizes acceptance (this treatment prevents clients from experiential avoidance) (Segal et al., 2002). There is an inverse relationship between mindfulness and experiential avoidance, and there is a direct relationship between anxiety and experiential avoidance. As a result, the conscious mind reduces anxiety (McCluskey et al., 2022).

Considerable changes in people's anxiety in the last year of their lives can be shown with the cognitive strategies of rumination, catastrophizing, self-blame, and positive reappraisal strategy. Evidence shows a strong relationship between cognitive emotion regulation strategies and symptoms of emotional problems. The relationships between the use of the cognitive emotion regulation strategies of self-blame, catastrophizing, and rumination and the report of anxiety symptoms, in particular, suggests that the presence of such symptoms might indicate the presence of maladaptive strategies of cognitive emotion regulation (Garnefski & Kraaij, 2007). Techniques that modify cognitive emotion regulation patterns are also used in MCT.

Detached mindfulness causes people to distance themselves from their thoughts and creates a metacognitive awareness of internal events. MCT is effective in reducing anxiety. The use of metaphor is one of the techniques of detached mindfulness. For example, people are taught to visualize their thoughts written on clouds that are moving away (Normann et al., 2014).

MCT focuses on reducing anxiety by modifying metacognitive beliefs about the dangerousness and uncontrollability of emotions. MCT focuses on meta-cognitive responses, such as choosing to let go of thoughts (Nordahl et al, 2018).

According to the research conducted by Hoffart et al. and by examining treatment interaction on a measure of the CAS, they concluded that MCT significantly affects positive and negative meta-cognitive beliefs (Hoffart et al., 2018). Another evaluation of the same study reported that negative automatic thoughts were reduced during treatment, suggesting that MCT was effective in improving meta-cognitions (Johnson et al., 2018). The analysis of self-report measures of negative automatic thoughts showed that most participants experienced an improvement in their symptoms at post-treatment and follow-ups.

The increase in anxiety was related to the rise in the left anterior and posterior cingulate of the right insula and the activation of the amygdala. tDCS by increasing dlPFC activity might affect autonomy by modulating the neural activity of subcortical structures such as the amygdala. Also, multiple evidence has shown that the reduction and upregulating of negative emotions are associated with increased dlPFC activity (Eippert et al 2007). Another study investigated that amygdala activity may cause negative reappraisal in the individual (Urrey et al., 2006). dlPFC does not directly influence amygdala activity related to emotional feelings, as there is no direct connection between the two brain regions. It is indirectly through the ventromedial prefrontal cortex, which is directly connected to dlPFC and amygdala (Hartley & Phelps, 2010). Thus, tDCS can reduce experiential avoidance by indirectly affecting the amygdala.

When a person focuses on the external environment, the dlPFC is a central area for cognitive processing (Miller & Cohen, 2001). In particular, dlPFC is one of the critical areas of the prefrontal cortex that plays a role in the cognitive control of emotional mechanisms (Ochsner & Gross, 2005). dlPFC is activated when a person has a conflict in simultaneously performing cognitive and emotional tasks (Ochsner et al., 2009). Since anodal tDCS increases the activity of the underlying cortices, it improves attention compared to emotion processing (Fregni et al., 2005).

Research has shown that people with anxiety disorders have problems managing their emotions (Amstadter, 2008). Recent findings show that left frontal tDCS can influence the reaction rate to negative content, and this issue displays that tDCS is effective in negative cognitive emotion regulation strategies in people with anxiety disorders (Marques et al., 2018). De Raedt et al. (2017) found that left dlPFC tDCS helped reduce spontaneous self-rumination. This research also shows that stimulation of the left dlPFC can reduce negative cognition (De Raedt et al., 2017).

Researches show a functional connection between prefrontal cortex areas and related subcortical areas, such as the amygdala, which allows for the modulation of threat-related structures (Ironside et al., 2019). Due to the effect of regional stimulation on brain networks, the impact of non-invasive brain stimulation methods on cortical areas is greater than on subcortical areas (Polania et al., 2012). However, the evidence shows that tDCS, by stimulating the dlPFC area, can also affect the activation and connection of subcortical areas (Polania et al., 2012; Weber et al., 2014).

The excitatory stimulation of the left dlPFC is used because of this region's association with reducing negative emotion (Pena-Gomez et al., 2011) and increasing positive emotion (Ollendick et al., 2002). Also, the evidence shows that the inhibitory stimulation of the right dlPFC decreases people's reactions to negative emotions (De Raedt et al., 2010). The right dlPFC and left dlPFC were the only targeted areas in the previous studies that have been conducted using tDCS to improve anxiety disorders. Even bilateral stimulation is suggested as a research proposal in the article of Vicario et al (2019). Yet, in this study, we investigated bilateral right and left dlPFC stimulation to increase the effectiveness of interventions.

Conclusion

MCT is a promising treatment in terms of acceptability and effectiveness on anxiety symptoms for GAD. In addition, our findings show that bilateral brain stimulation using tDCS in the left and right dlPFC regions reduces negative emotions. The results of our research show that dlPFC plays a vital role in regulating emotions in people with GAD. In conclusion, both MCT and tDCS were effective in GAD. However, MCT had a better outcome in reducing negative cognitive emotion regulation strategies in GAD. In future research, it is essential to compare the effects of these two treatments in follow-up over time.

Study limitations

There are also some significant limitations to consider. This study was limited to examining the effectiveness of mindfulness meta-cognitive therapy and tDCS on the psychological consequences of GAD. Evaluating the effectiveness of these two treatments on other outcomes of GAD, such as social and behavioral outcomes, can be another area of further research. GAD affects the level of irritability and social isolation. As a result, it disrupts the social relationships of people with GAD. Considering social and behavioral factors in future research better demonstrates the effectiveness of these two treatments. The second notable limitation is that due to the application of technology in the tDCS, the effect of hope for new and technological treatments could affect the treatment outcome. Future studies, including the placebo group, could eliminate the impact of psychological indoctrination. The third limitation that could potentially influence the results is the difference in duration of treatment. MCT treatment lasts longer than tDCS treatment, and this issue can affect the treatment result. In future studies, it is better to control the duration of treatment between the two treatment groups.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles were observed in this article. The participants were aware of the research process. They were also assured about the confidentiality of their information, and the research results would be available to them if desired. This study was approved by the Ardabil University of Medical Sciences (Code: IR.ARUMS.REC.1397.093).

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Authors' contributions

All authors contributed equally to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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