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# Stimulation or Meditation? Investigating the Effects of tDCS, Mindfulness and Personality Traits on Creative Thinking

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**Abstract**
Divergent thinking (DT) and convergent thinking (CT) are typically considered the two faces of creativity and are associated to different neuro-functional networks. Previous research underlined that brain stimulation and meditation can modulate the creative process. However, their effect over DT e CT is still not clear. Purpose: The aim of the present study was to explore if and how tDCS and mindfulness meditation could modulate creativity outcomes by administering a 4-day training whose efficacy was measured by a pre/post assessment. Method: Fourty-seven healthy volunteers were randomly assigned to four experimental conditions: A) real stimulation, real meditation; B) sham stimulation, real meditation; C) real stimulation, fake meditation; D) real meditation alone. tDCS stimulation was applied with the anode over F8 (Inferior Frontal Gyrus, IFG) and the cathode on the left supraorbital area for 20 minutes at 1.5 mA. Also, personality traits were considered. Results: Results revealed that training A was the most successful in improving convergent thinking and cognitive efficiency, while training C was more effective in modulating verbal fluency. Conclusions: Results have been discussed considering the role of IFG and the Default Mode Network (DMN) for DT and CT, together with personality attitudes. Also, future directions have been suggested.

**Keywords:** Creativity, Divergent Thinking, Convergent Thinking, tDCS, Brain Stimulation, Mindfulness, Meditation, Brain Modulation, Cognitive Psychology, Mind Wandering, Personality Traits, Experimental Psychology, Focused Attention, Cognitive Flexibility, Fluency

## 1. Introduction

Creativity has been defined as the ultimate resource of humankind (Findlay & Lumsden, 1988), receiving recognition and widespread attention in several fields. Being a complex construct both to understand and investigate, neuroscience has tried to unveil its underlying processes using different strategies.

One of the major tenets of contemporary creativity theories is the interplay of convergent (CT) and divergent thinking (DT) in yielding successful creative products or solutions (Kleinmintz et al., 2019). Convergent and divergent thinking are mostly thought of as being the opposite ends of a continuum, and they have been widely recognized to be both necessary to creativity (Runco, 2014; Zhang et al., 2020). Experiments targeting these two functions separately have thus taken up a big part of scientific endeavors in the field. Historically, DT has been considered as a proxy of creativity, and has thus been investigated more thoroughly than CT in creativity studies (Acar & Runco, 2019; Cortes et al., 2019). In the present work, the two complementary constructs have been explored.

Mindfulness is a meditation style that invites people to be aware of the impermanence of things within the here-and-now context and involves a specific attentional focus toward objects and sensations (Davidson & Goleman, 1977; Kabat-Zinn, 2015). Some studies reported that mindfulness improves a person's ability to focus attention and stay concentrated, thus favoring CT, while DT can be associated with the meditation power to promote a more open and flexible thinking (Brown et al., 2007; Eberth & Sedlmeier, 2012). Mindfulness seems to be useful in activating and modulating some mental aspects traditionally linked to creativity, such as curiosity, openness to experience, relaxation and focal attention, while reducing distractibility and the tendency to concentrate on a single aspect of reality (Prabhu et al., 2008). Interestingly, there is evidence supporting the view that mindfulness training favors the deactivation of specific brain areas (in particular, the medial prefrontal cortex) when processing aversive stimuli (e.g., painful stimuli (Taylor et al., 2011)), thus promoting emotion stability. This evidence seems to link studies on mindfulness and creativity with the study of DMN. Indeed, the MPFC plays a pivotal role in the default mode network (Gusnard et al., 2001). The focus on the present-moment is associated with decreased MPFC function, while a resting state activate it with a set of other connected areas (the inferior parietal lobule, the precuneus, the posterior cingulate cortex, and the inferolateral temporal cortex). However, it seems that mindfulness promotes a temporary deactivation of DMN even if, in people following a meditation training (long term effects) the internal DMN connectivity becomes long-term stronger (Jang et al., 2011).

On the other hand, vary moderators, such as the type of meditation practiced and the multifaceted character of mindfulness, do challenge untangling the mindfulness-creativity relationship (Baas et al., 2014). In detail, the two main types of meditation used in mindfulness research are open-monitoring (OM) and focused-attention meditation (FA). OM is the practice of observing and attending to any sensation or thought without focusing on any specific task or concept. FA instead trains the participant to focus their attention and awareness on a particular task, item, thought or stimulus. By coupling these two meditation techniques with RAT and AUT trials, studies have tried to assess FA and OM effects on CT and DT. In particular, FA has been associated with improved CT, while OM has been associated with DT (Colzato et al., 2012). What is more, task-independent changes in the DMN have been found in expert meditators, as well as enhanced activity in prefrontal areas, the anterior cingulate cortex and medial regions, such as the insula (Gundel et al., 2018; Lindsay et al., 2019).

An interesting phenomenon that has been associated both with OM and DT, engaging similar brain network activity, is mind wandering. While mind wandering seemingly runs contrary to mindfulness, it reliably correlates with creative thinking and creative achievement (Baird et al., 2012). Yamaoka and Yukawa (Yamaoka & Yukawa, 2016) found a link between frequent mind wandering and high level of creativity, while Agnoli et al. (Agnoli et al., 2018) showed that mind wandering and mindfulness predicted creative behavior both alone and in combination.

One of the techniques that has proven important in identifying the differential activation and shift between intrinsic brain networks in CT and DT is tDCS. While it is difficult to accurately determine tDCS effects, since individual and confounding variables have been found to affect treatment results, research on CT and DT has yielded interesting and unambiguous results regarding the differential contributions of the left and right temporal and prefrontal cortices to the creative process (for a comprehensive review, see (Lucchiari et al., 2018).

In particular, consistent results were obtained applying left cathodal/right anodal frontopolar cortex stimulation, revealing a key role of the right inferior frontal gyrus (IFG) and angular gyrus (AG) in improving performance and increasing cognitive flexibility in a variety of DT tests (Green et al., 2017; Ivancovsky et al., 2019; Koizumi et al., 2020; Stevens Jr & Zabelina, 2019). Furthermore, tDCS was found to affect brain networks, particularly the DMN, during creative thinking, and to modulate functional connectivity in flexible and creative ideation (Lifshitz-Ben-Basat & Mashal, 2021).

While decreasing left-hemisphere inhibitory control and executive dominance may trigger a general creative mindset, the following steps leading to idea generation, elaboration, and selection are yet to be clarified. Within this theoretical framework, for the present study we developed a 4-conditions sham-controlled experimental paradigm to assess creativity improvement using tDCS paired with mindfulness meditation (E-meditation; (Badran et al., 2017a, 2017b)).

Specifically, the present study aims to:
1) Determine if creative process can be modified by a) tDCS and b) E-meditation (tDCS in conjunction with an audio-guided Mindfulness procedure), and how.
2) Assess the relationship between mindfulness training and CT parameters.
3) Investigate the role that personality traits assume in modulating participants' responses to the different experimental conditions.

Based on previous research and the neuro-cognitive model illustrated above, we hypothesized that the tDCS+Mindfulness condition will have a greater effect than tDCS alone, which in turn will be more effective than Mindfulness alone (tDCS sham condition). We further hypothesized that Mindfulness alone has the power to increase convergent thinking as reported in previous research, and that this effect will be greater than Mindfulness+tDCS.

## 2. Materials and Methods

### *2.1. Participants*

Fourty-seven healthy volunteers ($M_{age}$=30, sd=9.36) participated in the experiment. The sample was composed of 34 women and 13 men. They all had normal or corrected-to-normal visual acuity. Previous history of psychiatric or neurological disorders was considered as exclusion criterion. The study was conducted with the understanding and written consent of the participants, who had been informed of the research procedures and purposes according to the Declaration of Helsinki and with the approval from the local Ethical Committee (Università degli Studi di Milano; protocol code: 27/19; 06/24/9).

### *2.2. Procedure*

Participants were randomly assigned to one of the four experimental conditions: A) real stimulation, real meditation; B) sham stimulation, real meditation; C) real stimulation, fake meditation; D) real meditation alone ($N_A$=13; $N_B$=10; $N_C$=14; $N_D$=10). Then, the procedure involved four different stages: I) Personality and Mindfulness Assessment. The participants, regardless of the experimental group, were asked to complete the questionnaires about personality indices, mindful and mind-wandering attitudes.

II) Pre-test assessment (T0). Participants were submitted to cognitive and creative tasks.
III) Training. Participants were asked to undergo 4-consecutive days of one of the four experimental conditions;
IV) Post-Training assessment (as in phase II).

### *2.3. Materials*

#### 2.3.1. Highly Sensitive Person Scale (HSPS)

(Aron & Aron, 1997)**:** sensory processing sensitivity (SPS), is a personality trait modulated by genetic factors, which allows people feeling and processing more information at one time, and in a deeper way. Such sensitivity is referred to both external and internal stimuli (Jagiellowicz et al., 2011). To measure SPS Aron & Aron (Aron &

Aron, 1997) implemented the HSPS, which includes 27 statements towards which the participant has to express their degree of agreement on a scale ranging from 1 ("totally disagree") to 7 ("totally agree").

2.3.2. Abbreviated Torrance Test for Adults (ATTA)

ATTA includes 3 different 3-minutes completion tasks. The first one requires verbal responses (Activity #1), while the second and third a figural output (Activities #2 and #3). The ATTA scoring consists of four norm-referenced abilities and fifteen criterion-referenced creativity indicators. The four norm-referenced measures are (1) Fluency; (2) Originality; (3) Elaboration; (4) Flexibility. The criterion-referenced indicators refer to additional qualities of mentioned or produced items (such as richness of imagery; humor; fantasy; etc). The final score was computed as the sum of these scorings (Goff & Torrance, 2002). The Creativity Index (CI) was considered for the purpose of the present paper.

2.3.3. Five Facets Mindfulness Questionnaire (FFMQ)

FFMQ is a self-report questionnaire developed by Baer and colleagues to assess the level of mindfulness experienced by individuals in everyday situations (Baer et al., 2006). It consists of 39 items to be answered on a Likert scale ranging from 1 (almost never) to 5 (almost always). It includes 5 facets of mindfulness: Not reacting to inner experience; Observing internal and external stimuli; Act consciously; Describing; Non-judging one's experience.

2.3.4. Mindfulness Awareness Attention Scale

The Mindful Attention Awareness Scale (Brown & Ryan, 2003) is a 15-item questionnaire which assesses dispositional mindfulness. Participants were asked to indicate how often they had experienced the scenarios and feelings indicated in the various items by using a 6-point Likert scale from 1 ("almost always") to 6 ("almost never").

2.3.5. BIG-5 Personality Questionnaire

For the purposes of the present paper we used the Big Five Inventory-10 (BFI-10) (Rammstedt, 2007), which consists of 10 items to be rated on a five-step scale from 1 ("disagree strongly") to 5 ("agree strongly"). It explores the Big Five Factor Model that includes the factors Extraversion, Agreeableness or Friendliness, Conscientiousness, Emotional Stability or Neuroticism, and Intellect or Openness to Experience.

2.3.6. Behavioral Inhibition/Activation Scales (BIS/BAS)

The scale includes 24 items (20 score-items and four fillers) to be rated on a five-point Likert scale from 1 "not at all true" to 5 "completely true" (Carver & White, 1994; Leone et al., 2002). The scoring included two subscales, one for BIS (7 items), and three for BAS (BAS-reward responsiveness; BAS-drive; BAS-fun seeking: 13 items).

2.3.6. Mind Excessive Wandering Scale (MEWS)

MEWS is a self-report scale assessing excessive mind wandering (Mowlem et al., 2019) with 15-items. Participants were instructed to assess the frequency of the proposed statement from 0 (never) to 3 (almost always).

2.3.7. Verbal Fluency

The verbal fluency task is useful for assessing the individual's ability to evoke words. Indeed, the participants are required to provide the greatest number of words belonging to a certain phonemic and/or semantic category, in one minute of time. For this experiment, we transformed the original oral version (Novelli et al., 1986) into a computerized task created with MatLab of both phonemic and semantic tasks. Participants were given 1 minute for each item. Fluency was assessed as the sum of the acceptable provided words (names, foreign words, derived words, and collective nouns were not accepted). The task reflects both linguistic and executive efficiency.

#### 2.3.8. Wisconsin Card Sorting Test (WCST)

The WCST provides a measure of higher executive functions including attention, working memory, mental flexibility, abstraction capacity, and the ability to modify mental paradigm. It is also useful for measuring the degree of perseverance. We chose a computerized version available on the online platform PsyToolkit.org. In the top of the screen 4 stimulus cards appear varying in color (red, yellow, blue, green), number (1 to 4) and shape (star, cross, triangle, circle) of the objects represented. With each trial, a card-target appears on the left side of the screen. Participants are required to match the target card to one of the four stimulus cards, following the criteria of color, number, or shape. However, the card-matching rule is not explicitly revealed, but must be inferred by monitoring the feedback ("right" or "wrong") provided after each trial. After a series of trials, the rule of pairing changes without warning: it is up to the participant to notice this and modify their responses accordingly. This version includes 60 trials and provides both verbal and auditory feedback. The cards have a size of 100x100px.

#### 2.3.9. Alternative Uses Tasks (AUT)

AUT stems from Guilford's research and is one of the most widely used tests to measure divergent thinking (Guilford et al., 1960). Participants are presented with an object with a request to indicate as many alternative uses as possible. For the purposes of our research, we created three computerized versions of the AUT using MatLab. Each version consists of 2 equivalent versions made up of two couples of common objects. The request was to list the greatest number of alternative uses for the object proposed. Participants had a maximum of 1 minute for each item. In this case, the scoring included fluency and flexibility measures of creativity. Fluency was simply scored as the number of appropriate answers, while, to measure flexibility, we created categories based on our sample, and then we counted for each subject the number of categories into which the items produced fell.

#### 2.3.10. Remote Association Test (RAT)

RAT was designed by Mednick (Mednick, 1962) to assess convergent thinking. Participants are presented with triplets of words that are not apparently related to each other, but that can be united by a fourth word that binds to all three: participants are required to identify this word as quickly as possible. Each triplet has only one response possible. For the purpose of our research, we created two computerized versions of the RAT using MatLab. Each version consists of 9 triplets, selected so that the difficulty level of the three tests to be equivalent, taking into account the Italian validation of the triplets (Salvi et al., 2020). Participants had one minute maximum to solve each triplet.

#### 2.3.11. tDCS protocol

For groups A, B, and C, tDCS stimulation was applied in the following positions: anode on F8 (Inferior Frontal Gyrus, IFG) and cathode on left supraorbital area. Active stimulation was delivered for 20 minutes at 1.5 mA. Sham stimulation consisted of applying 30 seconds of actual stimulation and then turning off the device. A commercially available Zendo tDCS system for meditation enhancement (Bodhi NeuroTech, Inc, USA) was used.

#### 2.3.12. Meditation

Participants in groups A, B, and D listened to pre-recorded mindfulness meditation audio-guide for 20 minutes. The practice was recorded by a trained researcher following a script which focused the experience on bodily sensations and breathing. Participants in group C have listened to a reading of a philosophical nature, recorded by the same person, using a tone of voice comparable to that of real meditation, for the same amount of time.

## 3. Results

After computing all the dependent variables related to personality traits, creative and cognitive performance, new dependent variables have been created to better highlight the gain (or loss) that each participant obtained thanks to the training. Thus, for creative and cognitive scores, deltas of performance have been calculated as the difference between the scoring obtained in T1 and those obtained in T0 (T1-T0). Then, 3 different sets of analyses have been conducted on the dataset.

### *3.1. Comparison of Delta scores across groups*

First, one-way ANOVAs were performed over each dependent variable (Delta scores of: Phonemic Fluency, Semantic Fluency, RAT hits, WCST total errors, WCST perseverative errors, WCST non-perseverative errors, WCST RTs, AUT fluency, AUT flexibility). The analyses highlighted a significant effect of Group ($F_{1,43}=3.14$, $p<0.05$; $\eta^2p=.18$) for Delta-Phonemic Fluency, with group C obtaining significantly higher gains (M=2.07, SD=.71) than group A (M=-.92; SD=.73) which, instead, performed worse after the training.

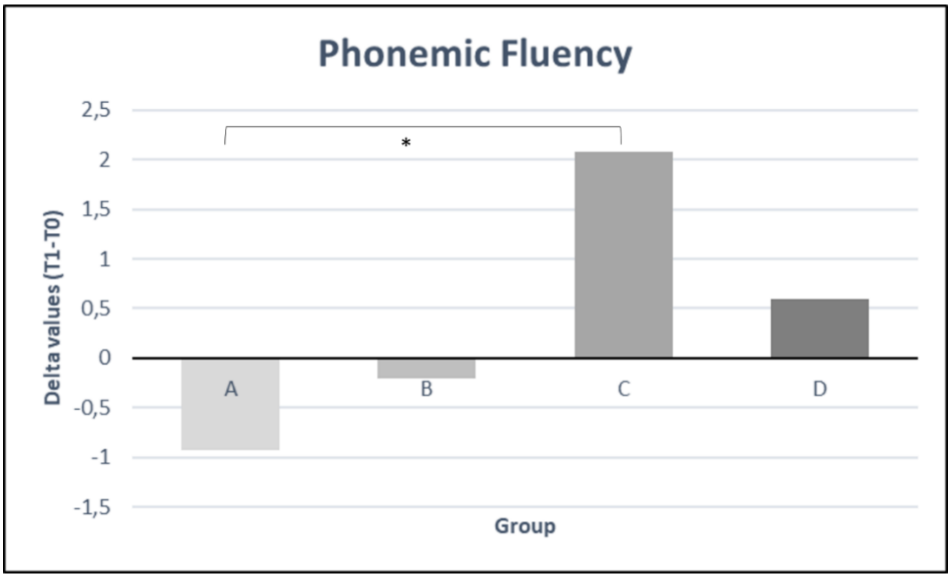


Figure 1: Histograms indicating the mean Delta Values (T1-T0) of group A, B, C, and D of Phonemic Fluency outcomes.

### *3.2. Pre/Post comparisons*

Then, 4 different sets of 11 t-tests (one for each dependent variable) have been performed within each group to compare the performance obtained before (T0) and after (T1) the training, for all dependent variables. Results showed that: in group A, four significant pre/post comparisons proved to be significant. RAT hits ($t_{1,12}=-3.4$; $p<.01$) were higher (M=5.85; SD=1.14) after the training with regard to T0 (M=4.15; SD=1.99), as well as WCST RTs ($t_{1,12}=2.75$; $p<.05$), which were lower (M=1393.4; SD=385.11) after the training with regard to T0 (M=1619.98; SD=241.63); WCST tot errors ($t_{1,12}=2.57$; $p<.05$), which were fewer (M=7.77; SD=2.17) after the training with regard to T0 (M=10.85; SD=4.02); WCST perseverative errors ($t_{1,12}=3.66$; $p<.005$), which were fewer (M=5.38; SD=1.26) after the training with regard to T0 (M=7.23; SD=1.88).

About group C, results revealed two significant pre/post effects: phonemic fluency was significantly ($t_{1,13}=-4.87$, $p<.001$) higher after (M=14.14; SD=2.54) than before (M=12.07; SD=2.2) the training. Also, WCST RTs were significantly ($t_{1,13}=3.75$; $p<.005$) lower after (M=1511.49; SD=418.27) than before (M=1792.09; SD=591.75) the training.

Finally, in group D, WCST perseverative errors were significantly ($t_{1,9}=2.34$; $p<.05$) fewer after (M=4.9; SD=2.03) than before (M=7.9; SD=4.07) the training. No significant improvement or worsening was found for group B in any of the dependent variables.

*3.3. Personality and gains*

Finally, we divided the personality variables into two groups according to frequencies (above or below 50%: high/low) or more (Torrance Creativity Level: from I, Minimal, to VII, Substantial creativity) and conducted a multivariate ANOVA for each group to see if there was any difference in the gains achieved after treatment. It was found that: considering HSPS in Group C ($p<.05$), low-trait group had very large improvements with dramatic reductions in WCST RTs after treatment (M=-467.62 ms; SD=94.98), while high-trait group had more modest improvements (M=-140.33; SD=82.25).

Also in Group C, Torrance Creativity level influenced the gains obtained after the treatment, with Level 5 - group obtaining significantly ($p<.05$) higher gains in AUT fluency (M=-7; SD=1.69) than the lower-trait (Level 1) group (M=5; SD=1.69).

Mind wandering attitude had effects on the gains obtained after treatment in terms of cognitive efficiency (WCST) in group A (total errors; $p<.05$) and group B (RTs; $p<.05$). People in the group with low mind-wandering improved little ($M_A$=-1.13; $SD_A$=1.28. $M_B$=70.33 ms; $SD_B$=224.27), while people with high mind-wandering improved more ($M_A$=-6.2; $SD_A$=1.62. $M_B$=-721.44; $SD_B$=224.27).

Mindful awareness in group C had effects on post-treatment gains in terms of flexibility in AUT ($p<.05$). The low-mindful group improved (M=1.17; SD=.67), the high-mindful group worsened (M=-1.38; SD=.58). Mindful awareness in group D had effects on gains in terms of non-perseverative errors in WCST ($p<.05$). The low-mindful group made more errors after treatment (M=1; SD=1.77), while the high-mindful group improved (M=-4.8; SD=1.77).

Finally, general Mindfulness trait in group A had effects on gains after treatment in terms of Phonemic fluency ($p<.05$): low-mindfulness group improved (M=2.25; SD=1.32), high-mindfulness group worsened (M=-2.33; SD=.88).

## 4. Discussion and Conclusions

The present study assessed the effects of a short E-meditation program (audio-guided Mindfulness + tDCS) on: cognitive flexibility (i.e., divergent thinking, convergent thinking and ideation); attention and mind-wandering; the perceived satisfaction and effectiveness of meditation.

Our results suggest that the E-meditation program is effective in increasing convergent thinking as measured by RAT and cognitive efficiency as measured by WCST. Interestingly, using the same stimulation protocol but subtracting the Mindfulness effect, we obtained substantial different outcomes. In particular, a meaningful increasing in fluency has been recorded, suggesting enhanced ideation. This combination of outcomes seems to suggest that the tDCS alone is effective in promoting ideas production, one of the most relevant aspects of creativity. Instead, the same stimulation with Mindfulness produces a focused functional state, which promotes convergent creativity, as if Mindfulness, keeping attention focused on the actual spatial and temporal context and limiting unfocused imaginative production (mind-wandering), was able to improve the frontal network coherence thus leading to improved cognition. Mindfulness was also effective in improving cognitive efficiency as measured by WCST but had no effects on RAT scores, thus supporting the idea that it is the E-Meditation protocol to elicit improved convergent creativity as a results of a double process: the tDCS inhibits some prefrontal control mechanisms thus allowing a fluent ideation process, while meditation channels this process toward a convergent one, that is the one needed to effectively solve the RAT. Hence, we may conclude that E-meditation is effective in increasing the convergent creativity, while short-term Mindfulness alone is not probable a procedure with specific effect on divergent thinking, being more effective in increasing cognitive efficiency. Our results are coherent with the conclusion of a meta-analysis (Lebuda et al., 2016) that highlighted ambiguity in the connection between mindfulness and creativity. Furthermore, Colzato et al. (Colzato et al., 2012) found that open-monitoring meditation increased divergent thinking outcomes, while focused-attention meditation (such as Mindfulness) affected convergent thinking.

However, our conclusions should be limited to the short training we used. Indeed, previous research found Mindfulness effective in enhancing one's creativity since it may improve concentration (Sedlmeier et al., 2012) in the long run. A Mindfulness training can also have a positive impact on the judgment tolerance, self-awareness regulation and open-minded thinking skills (Brown et al., 2007; Carson & Langer, 2006; Henriksen et al., 2020): key aspects of a creative personality (Selby et al., 2005). Furthermore, self-reported mindfulness skills correlate to creative practices (Colzato et al., 2012) and experienced meditators have been found to have better verbal creativity (Greenberg et al., 2012). Finally, Schooler et al. (Schooler et al., 2014) tested the effect of individual differences in mindfulness on RAT scores and found a negative correlation.

Other interesting results come from some trait parameters we have recorded about individuals' cognitive characteristics. In particular, since Mindfulness is purposedly directed to reduce mind-wandering, we tested if different mind-wandering attitudes could affect the outcome of our treatments. Actually, we found that participants with a low mind-wandering attitude reported a lower increase in post-treatment cognitive efficiency with respect to participants with high mind-wandering trait score. This result was found both for E-mediation (group A) and for sham+meditation (group B), suggesting that it is linked to Mindfulness. Thus, we may state that Mindfulness could be particularly useful to tune the cognitive control system toward specific task in people with a tendency to mind-wandering, and then with some difficulties in focusing attention and maintaining it on a task for a long time. Yet, the relationship between mind-wandering and creativity is uncertain and complicated.

Finally, tDCS alone (group C) effect was modulated the HS trait. High sensitivity is a cognitive characteristic that discriminates between people with low or high sensibility to sensorial stimulation. We found that participants low in HS reported a significant decrease in reaction times in WCST, suggesting an improved ability to process information and shift between rules after tDCS. Participants high in HS reported just a little decrease. Thus, the effect of tDCS, as well as E-meditation, should not be regarded only as a function of a neurobiological effect, since it is modulated also by individuals' characteristics, which should always be considered when delivering a certain mind- or neuro-modulation technique.

In conclusion, our study showed how the combination of transcranial stimulation and meditation may have positive effects on cognitive functioning and creativity, supporting previous research but also obtaining original results. However, some methodological constraints limit the possibility to generalize our outcomes strongly suggesting the need for further research. In particular, though the sample is quite large, each treatment was submitted to a limited number of participants. Indeed, we needed to determine the effect of the E-meditation program contrasting its effects with isolated treatments (meditation and tDCS alone). Future research could focus on E-mediation per se. Furthermore, differences in traits related to mindfulness expertise, creative attitudes and other personality factors may impact the results. Our study was not able to isolate these factors, since it was not possible to have group perfectly homogenous about these baseline characteristics. Future studies should evaluate the effect of E-meditation on previously screened participants, so to contrast expert vs naive as well as other fundamental individual parameters. Finally, we have used an audio-guided meditation that has the advantage to be standardized for every conditions. However, it is possible that in-presence experience may lead to somehow different results.

**Conflicts of Interest:** Authors reports no conflicts of interest to report in relation to this study.

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**Contributor Roles:** CL supervised all the study phases. CL and MEV developed the concept of the study as well as methods and implemented the experimental settings. CE and GR run the studies and collected data. CL and MEV conducted data analysis. CL, MEV and CE draft the first version of the paper, which was then finalized by MEV and CL. All authors approved the final version of the paper.

**Declaration of Generative AI and AI-assisted Technologies:** This study has not used any generative AI tools or technologies in the preparation of this manuscript.

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