• **Title –** Comparing minfulness and tDCS: a study on cognition and creative thinking

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• **Synopsis -** The current study investigates the differential effects of neurostimulation, mindfulness, and e-meditation over cognitive and creative performance. 47 healthy participants were randomly assigned to 4 experimental conditions: A) real stimulation, real meditation; B) sham stimulation, real meditation; C) real stimulation, fake meditation; D) real meditation alone. Before and after the treatment, a cognitive, creative, and personality assessment was conducted to investigate its efficacy. Results showed an improved performance on fluency in group C; on convergent thinking and cognitive task in group A; and on divergent thinking in group D. The differential effects of stimulation and mindfulness over different cognitive abilities could be further explored in future research.

• **Background -** Our daily cognitive and sensory experiences change exponentially fast, thus requiring individuals to exert a great effort in terms of neural adaptation. Our cognitive system needs to be flexible, and to switch from routine functioning to Creative-On mode, which allows reorganizing the perceptual field in an original way. Through this process the individual can produce concrete ideas that can be potentially useful in diverse contexts. Creativity can be enhanced by using neuroscientific techniques, such as neuromodulation and neurostimulation. This way the Creative-On mode, essentially based on a transitory functional reset of frontal cortices, can "unlock" creative thinking. This area, in fact, is involved in executive control and inhibition and its modulation can, thus, affect, different cognitive processes[1]. Another way to modulate cognitive functioning is meditation. Mindfulness in particular is a form of meditation derived from Buddhist meditation traditions in which the individual is instructed to maintain a state of awareness and openness to their surroundings in the present moment[2]. From a neurofunctional perspective, it has been proposed that mindfulness may be associated with improved cognitive skills such as the ability to sustain attention[3]. In the present work we aimed at investigating the differential effects of neurostimulation, mindfulness, and their combination (e-meditation[4)] over creative performance.

• **Methods -** Fourty-seven healthy volunteers (M_{age}=30, sd=9.36) participated in the experiment. The sample was composed by 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. Participants have been 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. Then, the procedure involved three different stages: I) Baseline Assessment (T0). The participants, regardless of the experimental group, were asked to complete the questionnaires about personality indices, mindful and mind wandering attitude. Also, they were submitted to cognitive task, such as Wisconsin Card Sorting Task (WCST), verbal and semantic fluency, as well as creative tasks, including the Alternate Uses Task (AUT) for divergent thinking, and the Remote Associate Task (RAT) for convergent thinking. II) Experimental treatment. This phase varied depending on the experimental condition and included 4 meetings distributed in consecutive days. Each meeting included a pre-treatment mood assessment, a 20-minute treatment, and a post-treatment mood assessment. III) Post Assessment. The participants were asked to repeat the same battery of questionnaires and tasks used in the baseline assessment after the first (T1) and fourth (T2) stimulation. 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.

• **Results -** Considering the numerosity of each experimental group, four different repeated-measures ANOVAs, were run, one for each group, with time as repeated factor (3 levels: before stimulation-T0, after the first stimulation-T1, and after the fourth stimulation-T2) and all the cognitive and creative measures as dependent variables. The aim was to identify, for each dependent variable, which group showed significant differences based on the time of stimulation. Results showed significant differences for: verbal fluency in group C ($F2,26=11.41$; $p<.0001$); RAT hits ($F2,24=6.46$; $p<.01$) and WCST errors ($F2,24=4.22$; $p<.05$) in group A; AUT RTs for group D ($F2,18=3.18$; $p=.066$).

Also, a mixed-model ANOVA was run on mood scores, with group as between factor, and session and pre/post as repeated factors. Results showed significant effects for the "stressed" component between the scores obtained before and after the stimulation, for all groups. Group A also showed a session*prepost effect. The "clear mind" component showed the prepost significant effect as well, but just for the D group. The "happy" component showed the prepost significant effect just for group B and D. The "calm" component also grew after the treatment for all groups. Group D also showed a session*prepost effect. The "restless" component was significant between pre and post treatment assessment for all groups. Also, in group B, it was significant among sessions, and in group C the session*prepost effect was also significant. Finally, bivariate correlations were run between the personality scores and the outcome variables, to investigate if the treatment gains were associated with any baseline trait. Significant correlations will be illustrated and discussed further taking into account the differential effects of the treatments.

• **Discussion -** The aim of the present study was to explore the effects of brain stimulation and meditation over different cognitive and creative skills. Results permitted to highlight some significant results to be further explored in future research. The B group did not show significant improvements after the treatment, which was, instead, detected for the two groups receiving real stimulation over F8, as well as for the group with only mindfulness meditation. The stimulation of the right IFG had favorable effects for both active stimulation groups over cognitive skills. This can be due to the fact that this area is recruited during executive control and salience detection[1]. However, the presence of real or sham meditation differentiated the outcomes for A and C groups. In detail: Real meditation has colluded with the effect of the stimulation favoring convergent thinking and cognitive efficiency (improvement in RAT and WCST). Sham meditation moderated this effect and promoted divergent and lateral thinking, probably because it involved more Default Mode Network (DMN) activity and spontaneous thinking, as well as mind-wandering, a phenomenon that seems to be linked to an increase in divergent thinking[5]. Finally, meditation alone promoted creative efficiency, probably because, without the engagement of the IFG and its executive role, the participants could switch the Creativity-on Mode. Also, the different treatments had specific effects also over mood states, with increased perceived clear mind just for group D, and increased perceived happiness in group B and D, the groups without stimulation. Finally, the improvements achieved as a result of the experimental procedure also depended on certain personality characteristics, which could be considered in the recruitment phase of future research to increase the chances of an effective empowerment pathway.

• **References:**

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