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The Creative Mind – DRACLE II Further Development

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Abstract

The presented performance, using an EEG-BCI (Brain Computer Interface), is dedicated to artists, scholars and experts interested in the whole world of creativity and the related psychological and neuro-cognitive mechanisms. The aims of this work are: to identify possible biomarkers (EEG) related to the creative process in specific tasks, exploring it in a real-time ecological setting; to investigate the relation between explicit and implicit mechanisms, between creativity personality trait, and semantic memory; to validate a tool to study creativeness. In a previous pilot study, we revealed the presence of significant relations between personality components, EEG indices and creative processes, suggesting that the use of a self-echo setting may be applied also to boost creativity in people with specific thinking styles and personality traits, and to empower creativity in a tailored fashion. In this paper we extended the experimentation, consolidating the previous obtained results.

Keywords

Cognitive science
Creativity
BCI
Emotion
Consciousness

Introduction

We can define creativity as the process that gives rise to new items (ideas and artefacts) and then we can define three kinds of creativity. In fact, new ideas may derive by combination, exploration or transformation (Boden 2004). From a cognitive point of view, creativity is a complex cognitive process resulting from the search of a balance between conscious and unconscious processes. When a new idea arises to the consciousness, and then a balance is achieved, the mind turns back to a “creative-off” state. Then, divergent thinking is replaced by canonical thinking. This perspective allows scholars not only to analyze human’s productions, but also to investigate if computers may show some kind of creativity and the related mechanisms (Boden, 2009). Thus, it is possible to collect empirical data that could be potentially useful beyond entertaining and artistic applications. Indeed, it is conceivable the design of cognition-driven environments in which creativity-on and creativity-off states are interconnected in a way to create pathways for cognitive empowerment. Moreover, such environments could also be used to improve emotion regulation (Gyurak et al., 2012), thus creating virtuous interactions between the cognitive and the emotional compartments. In this last case, the environments proposed by the present prototype could be particularly useful and motivating.

The performance, presented and discussed in this paper, is dedicated to artists, scholars and experts interested in the whole world of creativity and the related psychological and neuro-cognitive mechanisms. The aims of this work are: to identify possible biomarkers (EEG) related to the creative process in specific tasks, exploring it in a real-time ecological setting; to investigate the relation between explicit and implicit mechanisms, between creativity personality trait, and semantic memory; to validate a tool to study creativeness. It is the second step of a previous research on creativity. Being a very wide and complex phenomenon, we will consider here the perspective of Cognitive Science. In this field, human creativity is considered not just as the result of a cognitive encapsulated process, but as an online process linking together thoughts, emotions and sensory events in a complex fashion. Art and science are clear examples of the concrete enactment of this property, generally identified as “mental reflection”, allowing us to create a context in which we can give sense to the world.

The pilot study performed in our previous work revealed the presence of significant relations between personality components, EEG indices and creative processes, suggesting that the use of a self-echo setting may be applied also to boost creativity in people with specific thinking styles and personality traits, thus empowering creativity in a tailored fashion. In this paper we extended the experimentation, consolidating the previous obtained results.

The paper aims at explaining the possible benefits deriving from the contamination of Art and Science, in order to understand how mind and brain shape our experience through the dynamics of conscious and unconscious creativity mechanisms. We aim to contaminate the traditional academic thinking with the suggestions coming from the world of contemporary art and to introduce a discussion on the critical issue of the creativity mediated by technology and, as a counterpart, the creative mood of technology.

The acronym DRACLE comes from the names of the scholars and artists cooperating in this project (Dario, RAffaella, Claudio, Ludovico and Elide). Our group, born in the context of Neuro-aesthetic research and aimed at joining scientific research and Art, demonstrated that Art originates from our brain and is part of all the expression of our daily life. Eventually, we aim at reducing the distance between “Hard Sciences” and “Humanities”. The installation “The Creative Mind”, used for collecting data then analyzed in this paper, is focused on a real-time audio/visual representation of the creative process of our brain. Indeed, the installation allows analyze the individual creative process through a direct connection to the brain of a person, manipulating audio and video representation on a screen. The connection between the individuals' brains and the performance is realized by a B.C.I. (Brain Computer Interface) devices, described in the following paragraph "materials and methods".

The paper is organized as follows: a rationale of the experiment, the description of materials and adopted methods followed by the description of the performance, and then, in the final part, our conclusions and obtained results.

1.Rationale

Mind, environment and brain are historically connected concepts, intertwined and sometimes fused together. It is not possible to trace the trajectory of this conceptual path, but it is possible to think of its future that can be imagined as open, drawn on a background which, although variable, necessarily traces boundaries. Nonetheless, it is always possible to cross these boundaries by a process which includes all the three concepts, that is creativity.

Of course, we cannot give a unique definition of creativity, but we can state that, in general, it consists in the capacity of a system to draw new boundaries. The theoretical perspective proposed here refers to the application of an externalist model of the human mind to the construct of creativity, always immersed and depending on the environment. We could, indeed, compare the thoughts of our mind to a sort of software running on a biological hardware. In a complex system composed by mind, environment and brain, in which all the components overlap and define each other. We wish to recall the concept of "Complexification" introduced by John Casti (1995), who defines complexity as a hidden property of a system that shows up when an observing system (which could be called mind/brain), and an observed system (which could be called brain/environment) interact each other. When this happens, the effect is not only a form of complexity, but we obtain two different results: the first one is the "design complexity" which is in relation to the observing system; the second one is the "control complexity" which underlines the active role of the observed system on the observing system. Casti suggests that the best interactive situation between the two systems occurs when they show a comparable level of complexity, thus leading an observing system to project towards a higher level of complexity. The environment is not only the external component of the system, but it is tightly connected with specific mental operations on which it is possible to build an inside/outside boundary. Despite the absence of a boundary, indeed, it is possible to contemplate the presence of a link between the inside and the outside in terms of matter, energy, and information. Each environment would thus be the product of the observation through which a system constitutes itself by tracing a boundary with the outside. Accordingly, an environment is the effect of a building operation based on the cognitive filters applied by the observing system. Subsequently, this relation is creative by nature, and the environment is continuously defined through actions and mental operations. It is also important to consider that the environment as an observed system, and the mind as the observing system, are not separated, but one includes the other, and vice versa.

Considering this point of view, our study aims to consider creativity from a complex perspective. For this reason, we implemented an active exchange between a biological organism and an electronic device, making the individuals' brain interacting with the performance through the BCI device. In this way, we have two systems (an observed and an observing one) simultaneously part of a more complex one. Neither the observing individual, nor the observed computer can define what is happening, where the specific information comes from, and what it is about to happen, but such information, from both sides, is continuously processed and generates new information (visual and auditory outputs, neural firing, electric signal transmission, etc.). This process produces an instable system that nonetheless tends to stability, since the human brain can implicitly learn how to predict the situation, and how to enjoy it emotionally. Through this simple, but powerful paradigm, it is possible to observe a creative process in relation to the shapes and sounds in a non-conscious way. Also, it is possible to analyze how this process dynamically modifies the cerebral functioning (implicit learning), and how this reflects into the individual-environment interaction. This way it is possible to collect empirical data that could be potentially useful beyond entertaining and artistic applications. This is possible because the dynamic, active, and functional cortical re-organization is associated with the cognitive processes underlying learning and cognitive empowerment.

The present paradigm provides some points of novelty: first, the participants will not be asked to perform any task, but only to set their mind free to "create" thanks to the enactment of continuing cross-modal loop. Also, the creative process will be analyzed step by step in real time by means of EEG. Finally, particular importance was given to the role of the creative process in shaping human experience, thus situating the mind within its environment. In fact, our paradigm will allow the self-revealing to the mind/environment dynamics through the brain-computer interface. Indeed, the disclosure of something implicit (as the process through one's own mind connect with the world) can be considered a powerful phenomenon which could perturb both self-consciousness and the creative process. We may refer to this effect as "self-echo". In other words, the present project is focused on the relationship between self-consciousness and creative enactment.

2.Materials and Methods

Studies on creativity take advantages especially from EEG. This is due to its low invasiveness and high time resolution, making this technique fundamental to measure the response in terms of time elapsed from the stimulation and cerebral response, in that it allows for a much more refined temporal analysis of brain activation and can well capture the cognitive and emotional processes related to creativity within milliseconds. EEG provides, also, other useful information: the EEG power indicates the local activity of neuronal ensembles in a certain cortical area, whereas the EEG coherence in different frequency bands displays the degree of coordinated work of different brain regions (Bechtereva & Nagornova 2007). Neurofeedback, and more generally, BCIs, supply portable and easy-to-use solutions to explore such issues in a more ecological setting.

With the aim of collecting brain rhythms to show them interactively during the experiment, allowing the involved individuals to feel in comfort and free in movement, we chose to use a BCI device, a headset consisting in a simplification of the medical equipment for EEG (Allison et al. 2007), allowing to record cerebral rhythms and the direct brain-computer interaction. BCI devices are widely used in research, for the registration completely comparable to the medical EEG, but also for their low cost and high portability. Previous research with ecological meaning already explored the response to visual (Folgieri et al. 2012) and musical stimuli or creative acts (Folgieri & Zichella 2012) and recognize the emotions valence (LeDoux 2012; Folgieri & Zampolini 2014; Folgieri et al. 2014; Juslin & Sloboda 2012), and to reveal the mechanisms of the visual creativity (Folgieri et al. 2014).
The objective of many researches, past and in fieri, is understanding which are the mechanisms triggering creativity or characterizing the creative process (the insight). In some experiments the objective is to evaluate the emotive and cognitive response to visual-perceptive stimuli based on the concept of priming (Banzi & Folgieri 2012). Other studies investigate the mechanisms of response to colors (Folgieri et al. 2013), or to stereoscopy and monoscopy (Calore et al. 2012). The obtained results show interesting correspondences among some cerebral rhythms and the creative activity. Here we decided to use the Neurosky Mindwave, a new version of Neurosky MindSet[1], which accuracy and reliability has already been studied by Gri-

1 http://www.neurosky.com

erson and colleagues (Grierson & Kiefer 2011). The Mindwave is composed of a passive sensor positioned in Fp1 (left frontopolar) and from a reference sensor, positioned on the earlobe, used to subtract the common ambient noise through a process known as common mode rejection. This configuration is sufficient for our performance and research aims.

The chosen task is based on consideration revealed by Dietrich and Kanso (Dietrich and Kanso 2010), stating that existing work on the neuroscience of creativity fall into 3 categories: divergent thinking, artistic creativity, and insight. Nonetheless, except for a general recruitment of frontal areas, results are broadly inconsistent. In fact, according to the authors, creativity cannot be reduced "as a single, simple mental process or brain region" (p. 824). Also, research in the laboratory, under controlled conditions and with movement constriction, does not facilitate this ambitious aim.

Besides pure research, a few studies explored the topic of creativity by modulating, or reinforcing, some capacities that are thought to be related to creative processes. For example, neurofeedback has been used to teach participants how to self-regulate their neurophysiology; it has been used in groups of musicians (Egner & Gruzelier 2001, 2004) with significant improvement in music performance after the elevation of theta (4–7 Hz) over alpha (8–12 Hz) brain rhythms. In fact, EEG frequency bands reflect information processing, such as concentration, attention, as well as aspects of arousal, like tension, wakefulness, relaxation, or sleep, and neurofeedback technique makes individuals aware of these processes by feeding back a representation of their own electrical brain activity and allowing them to change it (Gruzelier & Egner 2004).

In the performance we used for our study, a BCI headset has been placed on the scalp of a performer, sending EEG rhythms to a computer which use it to modify bubbles and audio effects, varying dimensions, colors and the intensity and sounds. In detail, the algorithm we developed takes the data coming from the headset and computes the real-time theta/beta ratio, an index commonly a marker of the ongoing balancing between limbic and cortical structures that driven motivational and automatic responses (Schutter & van Honk, 2005). The change of this ratio is then used to modify some parameters of a complex shape made by several bubbles rotating around a pivot. These parameters are: the scale of the graphics, so that is can appear smaller or grater; the rotation speed; the direction of the rotation (clockwise or counter clockwise); the vertical and horizontal position on the screen. The combination of these parameters creates a uniform rotating movement across the screen. Furthermore, the sound track is initially selected through the Alpha rhythm power. Higher or lower levels of the set threshold define which music will be run. Then, during the performance, the theta/beta ratio is used to regulate the value of the sound (high vs. low).

The graphical and sound interface was developed using the open source 3D graphics and animation software Blender[2]. The next Figure 1 shows the user interface of the Blender development platform.

The graphical and audio objects were linked to the brain rhythm collected by the BCI in real time, using the interface library BrainWaveOSC[3], BrainWaveOSC was designed to transfer EEG data from Neurosky ThinkGear-based bluetooth EEG sensors to other applications like Max-MSP and PureData via the OpenSoundControl networking protocol.

3.Procedure

Twenty volunteers took part in the study. All the participants in the experiment did not use drugs or narcotics or medicines of any kind. Half of them were familiar to Arts (music, paintings...), while half of them were naïve. Participants were asked to read and sign an informed written consent, then, they were required to com-

2 https://www.blender.org/
3 https://github.com/trentbrooks/BrainWaveOSC

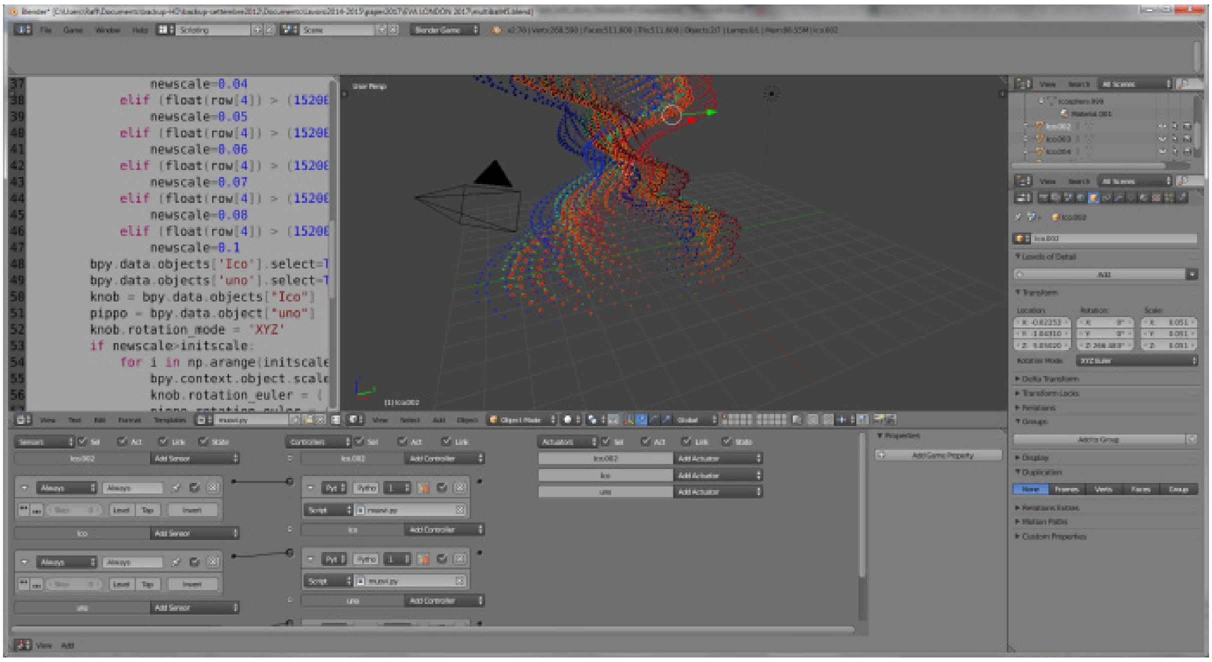


Figure 1. The Blender platform used to develop graphical and audio object of the performance.

plete the Behavioral Inhibition System/Behavioral Approach System Test (BIS/BAS) and the Big Five Questionnaire (BFQ).

We also wanted to measure the span of memory by repeating series of numbers, with two tasks. In the first, the experimenter read the numbers slowly, which the participant had to repeat in the same sequence. In the second, there was another list of numbers to be repeated in the reverse order to that used by the experimenter.

Therefore, participants were asked to read a brief study description: in the case of the members of a first group (aware: A), the sheet contained all the details about the content and purpose of the experiment; the members of the second group (unaware: UA) simply knew from the instructions that they would have taken part in a generic experiment on creativity, where they would be asked at some point to watch 3D animation on a screen.

Apart from the completeness of the information on the study, the experiment took place in the same identical way for both groups. Our purpose was to see if there was a different involvement of alpha, theta and gamma waves between those who knew what they were doing and who was unaware of the situation. So, Group 1 was aware (A) of the fact that the BCI device would allow them to interact with the graphic interface, while subjects in Group 2 only known that the BCI would register their brain functioning (UnAware Group).

After the montage of EEG headband (BrainBand XL) and the launch of BrainWaveOSC and Blender programs, a resting baseline was recorded (2 min eyes closed + 2 min eyes open;) with BrainWaveOSC. After these steps, participants received instructions by the experimenter to guide the different conditions during the creative task. The instructions were displayed on the screen and were referred to different experimental conditions. Before beginning with the 5 conditions, a 1-min free-run period was recorded. The instruction was: “Set your mind free to interact with the computer interface”. After this run, the other 5 conditions were presented randomly; each condition lasted 1 minute, and a 1-min pause was administered between conditions. Together with the instructions, 3 words intruders (written in brackets in the examples below) have been presented to the participants. The intruders were 3 examples within the semantic category. The instructions were: “Concentrate and try to focus on...”:

- Concrete task: “a concrete object” (like “shoes”, “leaves”): Task Cn;
- Abstract task: “an abstract concept” (like “sympathy”, “justice”, “happiness”): Task A;
- Color task: “a color” (like “blue”, “red”, “green”): Task Cl;
- Place task: “a place you know” (like “home”, “hospital”, “university”): Task Pl;
- Person task: “an important person for you” (like a relative, a friend, a famous person): Task P.

During each task, participants watched the screen with Blender’s DRACLE animation programmed with Python, accompanied by different music, like Yann Tiersen piano or other ambient songs. This animation consisted of round shapes of different colors that made movements uniformly in a three-dimensional space, usually turning around the 3 axes.

Finally, subjects were required to write a story down by using the 5 words and the related semantic fields previously imagined during the tasks. The instruction was: “Now we ask you to take some time to write down a story by using the concepts you experienced during the 5 experimental trials (color, concrete word, abstracts concept, place and person).

After a 2 minutes break from the story, participants were asked to compile some questionnaires to assess imaginative abilities, such as the Vividness of Visual Imagery Questionnaire (VVIQ) and the Test of Visual Imagery Control (TVIC).

Finally, the Torrance Test of Creative Thinking (TTCT) was administered.

4.Results

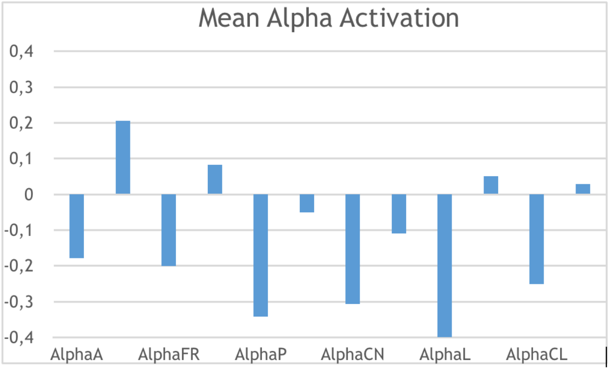
Correlations

The strongest correlations of the Torrance creativity test were with the stories written immediately after the end of the BCI phase. The number of words, nouns, adjectives and, in part, adverbs, goes hand in hand with the ability in verbal fluidity, flexibility, processing and originality; more unexpected the correlation between the figurative elaboration and the use of words, above all names. Higher scores in fluidity, flexibility and verbal originality are negatively correlated with the use of intruders, the examples placed between brackets in the sheets with instructions. We can say for certain that greater knowledge of vocabulary and greater originality have made the individual less permeable to our intruders, given by the reduced effort made to look for an idea or a word that was outside the text they had in front of their eyes.

Analysis of Variance (Anova)

ANOVA revealed the difference in the activation of all the frontal waves between aware and unaware groups. The first group had a lower activation of alpha than the mean average of all EEG values. Group 2 participants, on the other hand, had almost always higher values than the mean average. In both groups, considering each frequency, almost all components have kept the constant of running less (Group1) or more (Group2) than the statistical mean. AlphaP (M = -0,0495278; SD = 0,47) and AlphaCN (M = -0,10837388; SD = 0,29), although the negative values, are still closer to 0 than Group1. Group1 has the lowest values in AlphaL (M = -0,39; SD = 0,26) and in AlphaP (M = -0,34; SD = 0,35). We found significant results in alpha t-Test ($t(17) = -1,61$; $p<0,05$).

This is the most important result that underlines how aware and unaware participants reacted to the different conditions: in Group 1, general activation was almost always lower than in Group2. These parameters are also linked to the values of attention and meditation, which were decisive in the final results. The first group, linked to the instruction to be creative, have more easily fallen into a meditative state; those in the second group were more intrigued by the animation of Blender and by trying to understand what was happening, therefore a higher attention.



We found similar values also in theta. In this case it was more relevant in the analysis of variance with thetaz (z to verify whether the average value of the distribution differs significantly from the reference value), especially in ThetazA and ThetazL.

Also, for what concerns TTCT, an analysis of variance on intruders was performed. A higher average number of intruders emerged in Group1 than Group2, which could be related to a greater permeability of the first group to examples with respect to the second sample.

Conclusion

Our study permitted to explore the correlation between physiological data, personality traits and levels of creativity. The EEG data confirm, in part, previous studies. Participants could have found a real or evocative figure in it, even if for many participants it was simply an animation to watch, letting their minds to be 'transported'. Given the activation and deactivation of certain bands, the BCI could be used to stimulate creativity it-self. Understanding the response in frequencies to some stimuli starting from certain thoughts, whether concrete, abstract or emotionally engaging, can lead us to understand how to stimulate those frequencies in terms of a greater interaction with a graphical inter-face, or improve the stimulation of creativity simply observing moving images. The fact that there have been more correlations and significance of results with the most creative people shows us precisely which frequencies are most used by them, and therefore those to work on so that even the least creative people can reach the same levels.

In fact, we found different associations between these elements, in first instance the relationship between BAS drive, BAS fun seeking, BFQ openness and levels of creativity. Often, very creative people are in fact considered to be open to the world and to new experiences, without setting too many limits when they want to do something; they are also considered a bit childish at times, in the constant search for fun and not inclined to respect the rigidity of the rules. The creative person wants to have fun and entertain, often coming out of schemes and boundaries. "I do something because I enjoy doing it": there is pleasure from the task itself (intrinsic motivation) rather than from the benefit that comes once the work is completed. The latter is a motivation of an "extrinsic" nature and is more typical of "non-creative" people. Moreover, the "extrinsic" interests can interfere with creative thinking and thus jeopardize its "natural" development because the evaluation by an external subject could restrict the freedom of choice (Amabile, 1990). Openness is the most important trait of personality for creativity. Mental openness (or openness to experiences) is the best indicator of creativity according to the common academic consensus (Chamorro-Premuzic, 2015; Vohs et al, 2013): it is practically the synonym for creativity. This trait is characterized by imagination (vs. practicality), by curiosity, by the non-traditional. People who are mentally open and creative are aesthetically sensitive (attracted by various forms of art), intellectually curious and, in general, open to new experiences. We can therefore affirm that the level of creativity and the personality traits are connected, so that one could interfere with the other.

A high level of creativity has also shown a lower permeability to the examples of the external world, confirmed by the negative correlation with the “intruders” in the final narrative. The creative has the world in his head, assimilates everything, but reworks it in his own way.

The reason why the second group has had a general greater activation than the first, especially in alpha and theta, remains uncertain. In part the difference could be given by a greater level of creativity and openness, on the other the condition of knowing or not knowing what they were actually doing during the experiment. This factor, although not fundamental, could be important in the development of new technologies and in their functioning.

Our results could also find usefulness for rehabilitation, improving cognitive performance. Just as they could be useful for entertainment, in order to create a new art form linked to technology and BCI. “In cognitive science, the functioning of the brain and the achievements of art are considered together to explain our aesthetic experience… For instance, it is possible to explicate why sometimes the reading of some images may depend on a subjective interpretation, based on the personal and sentimental response despite to perceptive cues, as colors and their contrasts.” (Lucchiari, 2017). During the interaction with Blender many participants, in fact, declared to have thought of many scenarios despite the focus on the initial image required, facilitated by what they had on the screen and the music they were hearing. We need to understand how much music has influenced EEG data; comparing people who had had experiences with music and those who had not, there were no significant differences in activation, except a slight increase in beta activation in musicians. It must be said that this study investigates only the frequencies emitted by the frontal lobe, while the differences between artists and other categories are more evident in the temporal lobe.

Previous research in recent years conducted on brainwaves aimed at improving the functioning of BCI. Scientific and technological research tries to go hand in hand, walking together towards a single goal: the improvement of human life and the introduction of a new way of perceiving and developing reality. The field of use can range from medicine to gaming, from rehabilitation to new forms of art. In short, it could be the future. The various tools that allow brain-computer interaction are based on general electrical activity and on the activation of the different frequency bands; a better understanding the relationship between this and specific thoughts and activities can lead to an incredible improvement in this area. Although these studies are already well under way (see for example Banzi & Folgieri, 2012; Bechtereva & Nagornova, 2007; Folgieri & Zichella, 2012), there are still numerous steps to be taken. In this context, our paradigm provides some points of novelty: first, the participants are not asked to perform any task, but only to set their mind free to “create” thanks to the enactment of continuing cross-modal loop. Also, the creative process was analyzed step by step in real time by means of EEG. Finally, and more importantly, particular importance was given to the role of the creative process in shaping human experience, thus situating the mind within its environment. In fact, our paradigm allowed the self-revealing to the mind/environment dynamics through the brain-computer interface. Indeed, the disclosure of something implicit (as the process through one’s own mind connect with the world) can be considered a powerful phenomenon, which could perturb both self-consciousness and the creative process. We may refer to this effect as “self-echo”. In other words, the present project is focused on the relationship between self-consciousness and creative enactment. Such environments could also be used to improve emotion regulation (Gyurak et al. 2012), thus creating virtuous interactions between the cognitive and the emotional compartments.

In this last case, the environments proposed by the present prototype could be particularly useful and motivating.

To conclude, the present pilot study permitted to underline some preliminary data about the presence of significant relations between personality components, EEG indices and creative and imaginative processes. In particular, in future research, it will be possible to analyze if the use of a self-echo setting may be applied not only to investigate statistical correlations and/or the presence of neuropsychological correlates, but also to boost creativity in people with specific thinking styles and personality traits, in a way to empower creativity in a tailored fashion. Indeed, we argue that creativity is a personal feature that should be addressed in a complex setting able to take together several different components. In this way, we might substitute the "creativity-pill" approach with a more effective self-adaptive boosting process" (Lucchiari et al., 2017).

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